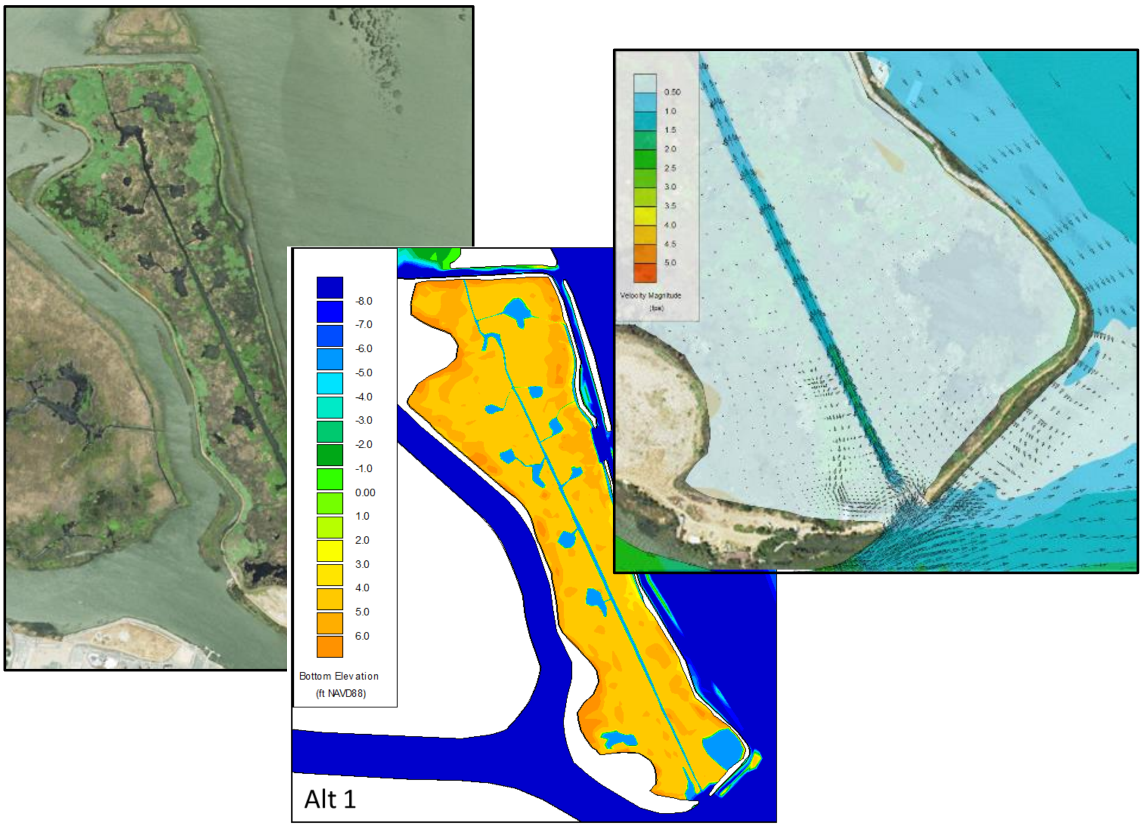
Initial Modeling of Local and Regional Impacts of the Proposed Winter Island Tidal Marsh Restoration
Technical Memorandum

July 2015



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Executive Summary

Numerical models for hydrodynamics and water quality transport have been applied to evaluate Local and Regional Impacts of the Proposed Winter Island Tidal Marsh Restoration Project (Project). The Winter Island restoration site was added to the latest version of the RMA Delta model in its current state with a single breach on the east side and with two alternative restoration configurations. Prospect Island restoration was included in all simulations under the assumption that it will be constructed prior to Project restoration.

The Alt 1 restoration alternative includes widening the existing breach on the east side of the island and adding a new breach at the south end of the island. Alt 2 adds another breach at the north end of the island.

Two sets of Base and Alternative simulations were performed using different marsh plain elevations to test sensitivity to possible LiDAR data bias.

The analysis was performed for May through November of 2009 and 2013.

Alt 1 and Alt 2 resulted in similar EC impacts. Alt 1 tended to have slightly larger impacts with the Base-1 scenario, while the reverse was true with the Base-2 scenario.

The lower marsh plain elevations in the Base-2 scenario resulted in a noticeably larger EC impact.

The largest EC impacts occurred in the San Joaquin River near Antioch and Jersey Point and into False River. Changes did not exceed 1% for the Base-1 results or 2% for the Base-2 results.

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Introduction

This report provides a detailed description of initial numerical modeling for the Winter Island restoration. Regional salinity impacts resulting from the restoration are evaluated. Electrical conductivity (µmhos/cm), or EC, was modeled as a surrogate for salinity. Details are provided describing model boundary condition data sources and the application of boundary conditions in the model.

Background

Winter Island is an approximately 450 acre private duck club located at the confluence of the Sacramento and San Joaquin River. The island is being considered for tidal marsh restoration. In its current state, the island is open to the San Joaquin River through a single breach that is approximately 200 feet wide. A constructed channel runs the length of the island in a north-south direction, with several small ponds extending from it.

Objectives

The objective of this study was to evaluate regional salinity impacts resulting from Winter Island tidal marsh restoration alternatives. Two breach configuration alternatives were considered. To address the issue of uncertainty in Winter Island elevation data, additional simulations were performed to assess sensitivity to marsh plain elevations.

RMA Delta Model

The RMA Delta model has been used for this analysis. The RMA Delta model is a well-established tool for analysis of hydrodynamic and water quality impacts of proposed projects in the Sacramento-San Joaquin Delta.

The RMA Delta Model was chosen for this study due to its ability to provide sufficiently accurate simulation of Delta-wide hydrodynamics and water quality transport and its ability to perform predictive simulations to evaluate the impacts of proposed tidal marsh restoration. The RMA Delta Model utilizes the RMA2 hydrodynamics and RMA11 water quality transport finite element computational engines. The finite element model formulation allows use of an unstructured computation mesh where resolution can be increased locally to represent the topographic details of a restoration site. RMA2 and RMA11 engines support combining two-dimensional depth-averaged (2D) computational elements and one-dimensional cross-sectionally averaged (1D) elements in a single mesh. In the RMA Delta Model all large channels, embayments, and tidal marsh restoration areas are represented in 2D. The model has been shown to provide accurate simulation of tidal exchange through constrictions, such as levee breaches into a restoration site, based on the breach geometry, site topography, and friction parameter (Manning's n value) estimated within typical accepted range.

The model does not directly simulate the effects of stratified flow, which would require application of a three-dimensional (3D) model. The effects of stratification are approximately incorporated into the model through calibration exercises where mixing coefficients are adjusted to best represent the observed salinity field for a historic period, or to best represent the simulated salinity field from a 3D model simulation for a proposed condition.

When performing numerical modeling to predict system performance for physical or operational conditions where field observations are not available, it is important to ensure that the mathematical formulation of the model appropriately represents the relevant physical processes and can provide sufficient geometric detail. For analysis of tidal marsh restoration that is not expected to have large impacts on stratification, such as this analysis of the Winter Island site, the RMA Delta Model is an appropriate choice.

Geometric Extents

RMA's Sacramento–San Joaquin Delta network was developed using an in-house GIS-based graphical user interface program (RMA, 2003) and the commercially available Surface-water Modeling System (SMS) software by Aquaveo, LLC. The program allows for development of the finite element mesh over layers of bathymetry points and bathymetry grids, GIS shapefiles and aerial images.

The RMA Delta model, shown in Figure 1, extends from the Martinez at the west end of Suisun Bay to the Sacramento River above the confluence with the American River, and to the San Joaquin River near Vernalis. A two-dimensional depth-averaged approximation is used to represent the San Francisco Bay, Suisun Bay region, the Sacramento-San Joaquin confluence area, Sherman Lake, the Sacramento River up to Rio Vista, Cache Slough, Liberty Island, Shag Slough, portions of Lindsey Slough, the Sacramento River Deep Water Ship Channel (DWSC) and Miner Slough, Big Break, the San Joaquin River up to its confluence with Middle River, False River, Franks Tract and surrounding channels, Mildred Island, Old River south of Franks Tract, and the Delta Cross Channel area. The other Delta and Suisun Marsh channels and tributary streams are represented using a one-dimensional cross-sectionally averaged approximation.

For the purpose of this project, Winter Island in its current state has been added to the model network. The Prospect Island planned restoration has also been added as it is expected to be constructed in the near future.

A detail view of the Project area, is shown in Figure 2

Bathymetry

Delta model bathymetry is shown in Figure 1 for the Base case. A comparison of Base and Restoration case model bathymetry in the Project region is shown in Figure 2. For all areas of the RMA2 model grid, the most current, best quality bathymetric data were used to set grid elevations.

The model was refined in the project area with added detail in the channels around Winter Island. Elevations in the surrounding channels were set using the latest Digital Elevation Model (DEM) developed by Department of Water Resources (DWR): http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/modelingdata/DEM.cfm

The DEM website was also the source of 2m Delta bathymetry data collected from recent multi-beam surveys. The site also provides a figure displaying the original data sources for the most up to date Delta bathymetry data.

Within Winter Island, marsh plain elevations were set using the 2009-2011 CA Coastal Conservancy Coastal Lidar Project DEM: https://data.noaa.gov/dataset/2009-2011-ca-coastal-conservancy-coastal-lidar-project-hydro-flattened-bare-earth-dem All Winter Island marsh channel and pond elevations were set at -5.9 feet. This elevation was estimated based on data from neighboring marsh areas (WWR, 2006).

Due to uncertainty in this data set and the possibility that elevations could be biased high due to marsh plants, a set of model grids were created with Winter Island marsh plain elevations lowered by 1.6 feet to test sensitivity.

Bathymetry in the Cache Slough area were set using bathymetric data collected in 2012 by DWR (DWR, 2012) and Environmental Data Solutions (EDS, 2013), in 2009 by cbec (cbec, 2011) and in 1997 and 2005 by USACE data (USACE, 2005 and 2002). Coarsely space single beam transects from the Central Valley Floodplain Evaluation and Delineation (CVFED) (cbec, 2011) were used to set model elevations in various locations in the northern Delta and Sacramento River.

For all other areas, bottom elevations and the extent of mudflats were based on bathymetry data collected by NOAA, DWR, USACE and USGS. These datasets have been compiled by DWR and can be downloaded from DWR's Cross Section Development Program (CSDP) website at http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/csdp/csdp.cfm. Topography data from DWR's Delta LiDAR survey (2007) was used where elevation data for channel banks, tidal marsh and flood plains was not available from the other sources.

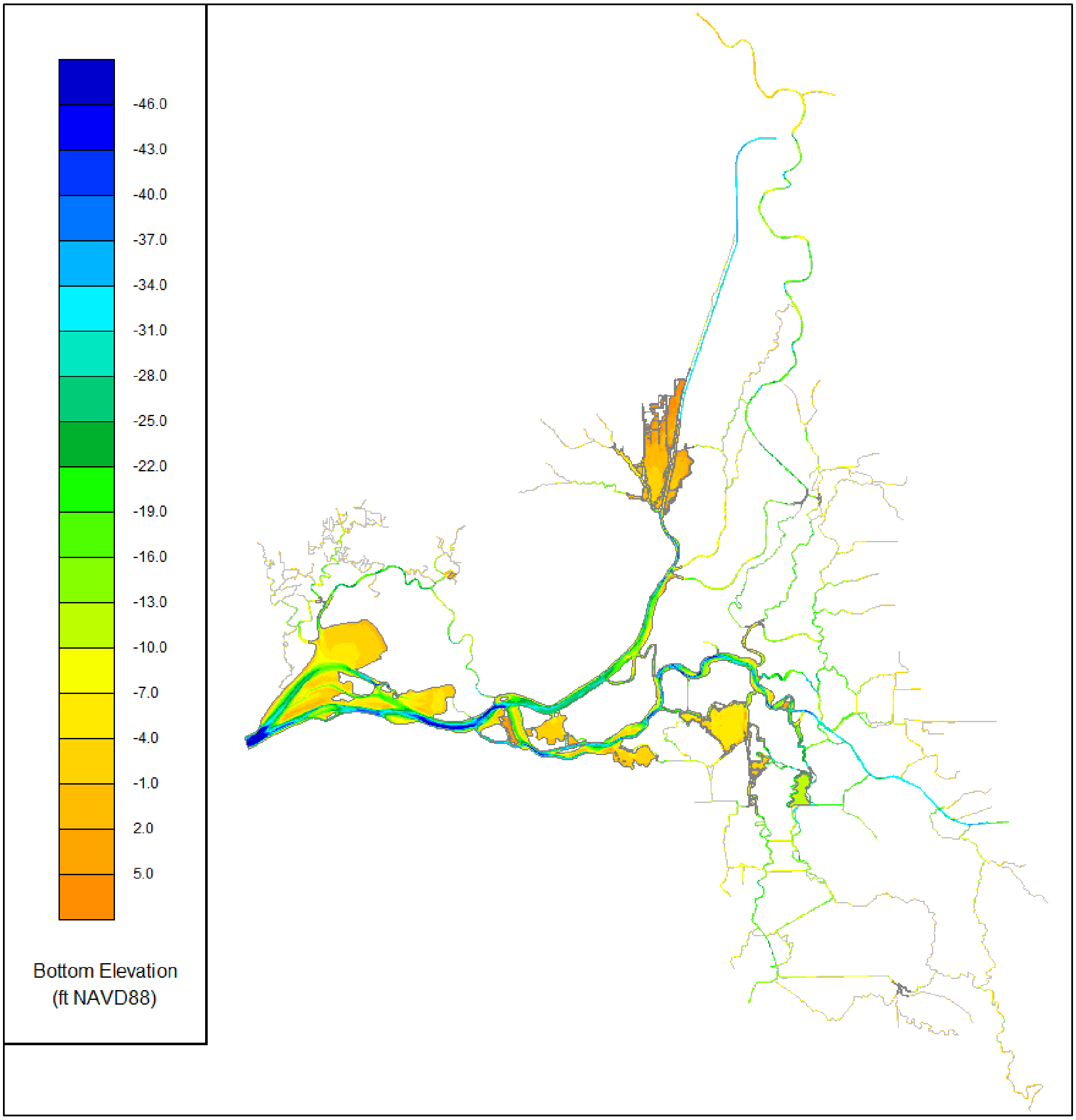

Figure 1 Base case model bathymetry.

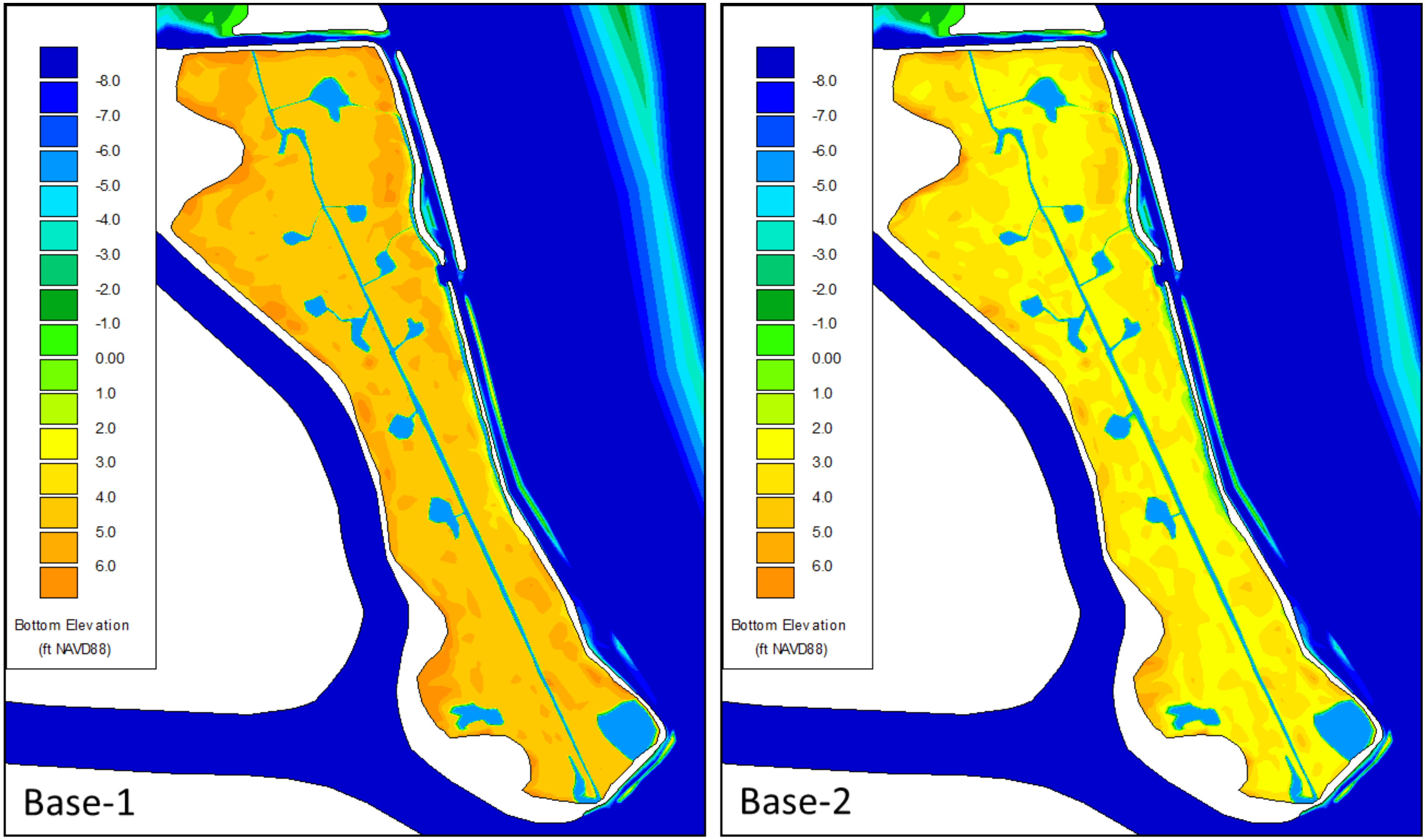

Figure 2 Model bathymetry in the Project vicinity for the two Base configurations.

Boundary Conditions

The RMA Delta hydrodynamic model operation requires specification of the tidal stage at Martinez and inflow and withdrawal rates at other external boundaries as shown in Figure 3.

Hydrodynamic and water quality models were run for the January – November 2009 and January – November 2013 periods. The January – April period was used for model spin-up and May through November results were used for EC impact analysis. The 2009 simulation period includes below normal, dry and critically dry conditions and the 2013 period includes dry and critically dry conditions (see http://cdec.water.ca.gov/cgi-progs/iodir/wsihist). Delta outflow for both periods is plotted in Figure 4. Tidally averaged EC at Martinez is plotted in Figure 5 for both periods.

Boundary conditions for the 2009 and 2013 simulation periods are detailed in the Appendix.

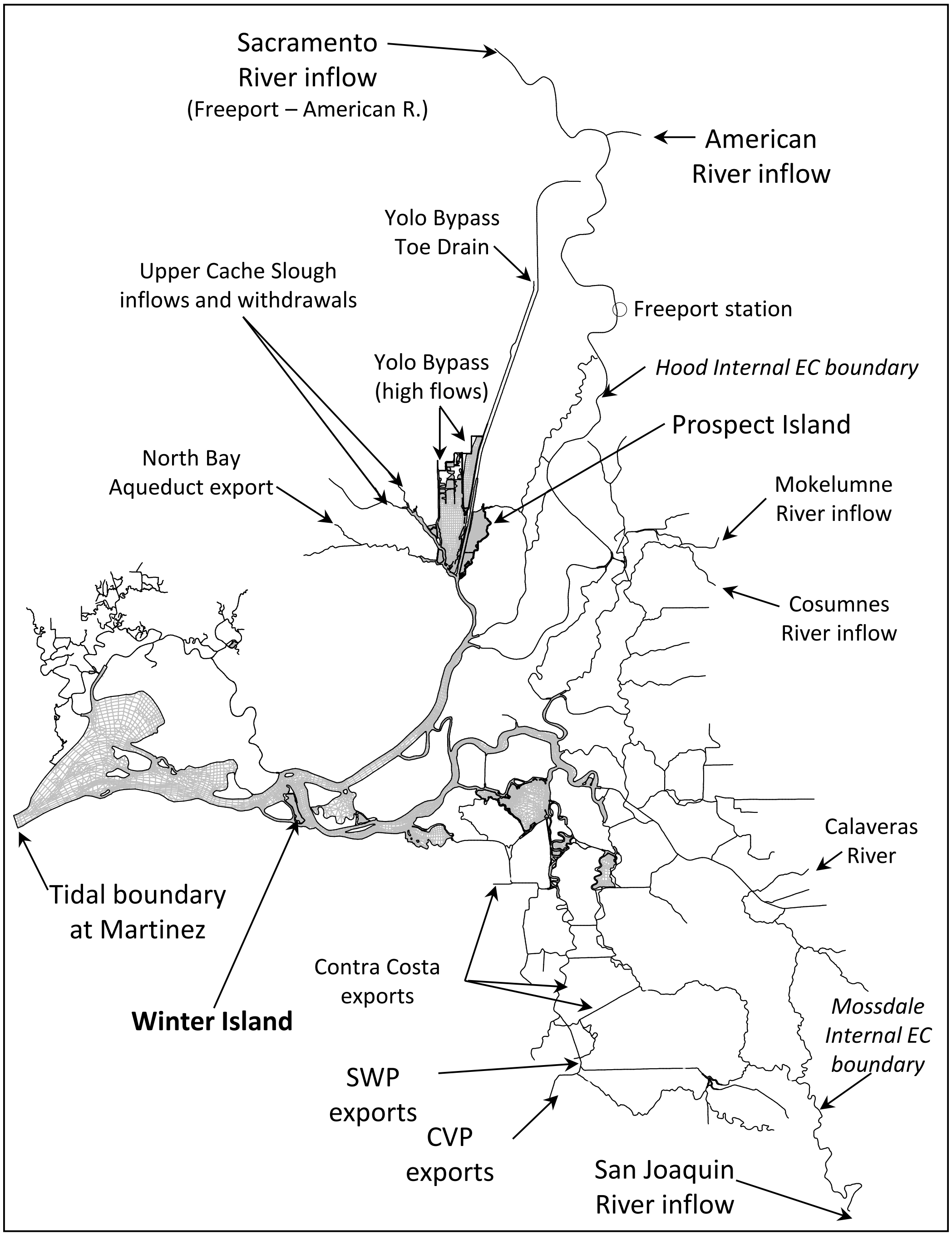

Figure 3 Model boundary condition locations.

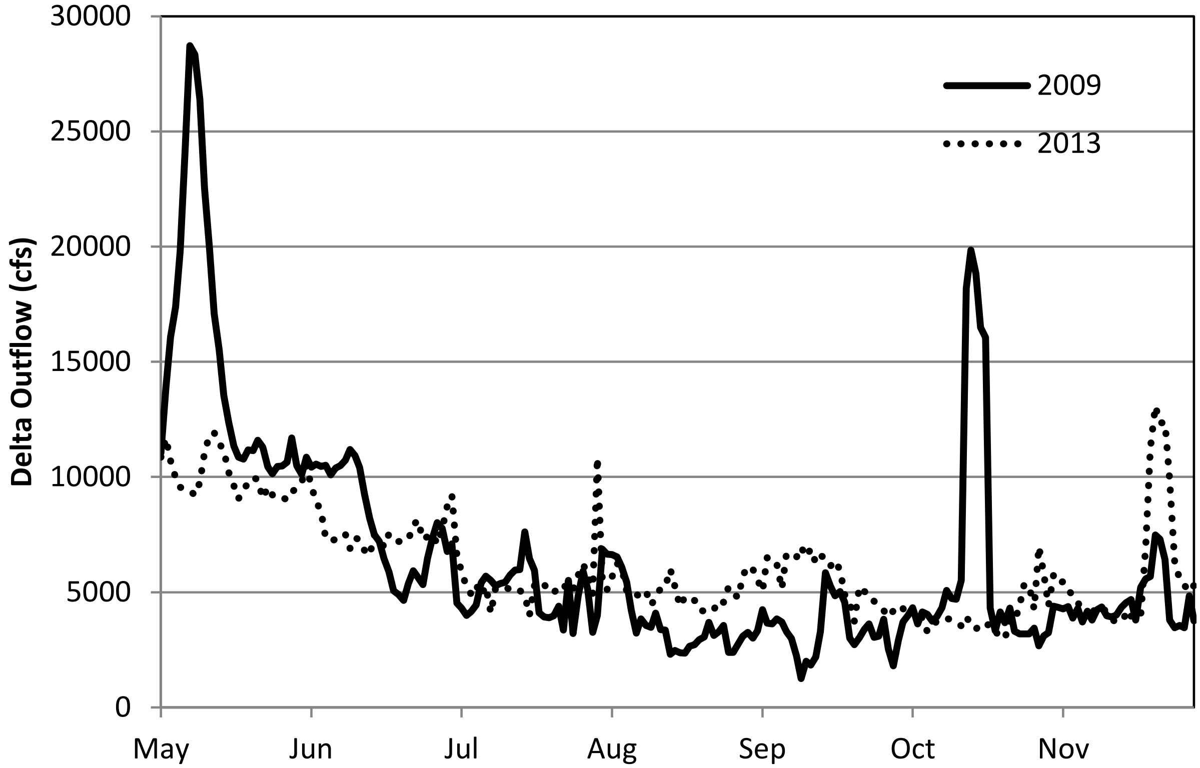

Figure 4 Delta outflow for the 2009 and 2013 analysis periods.

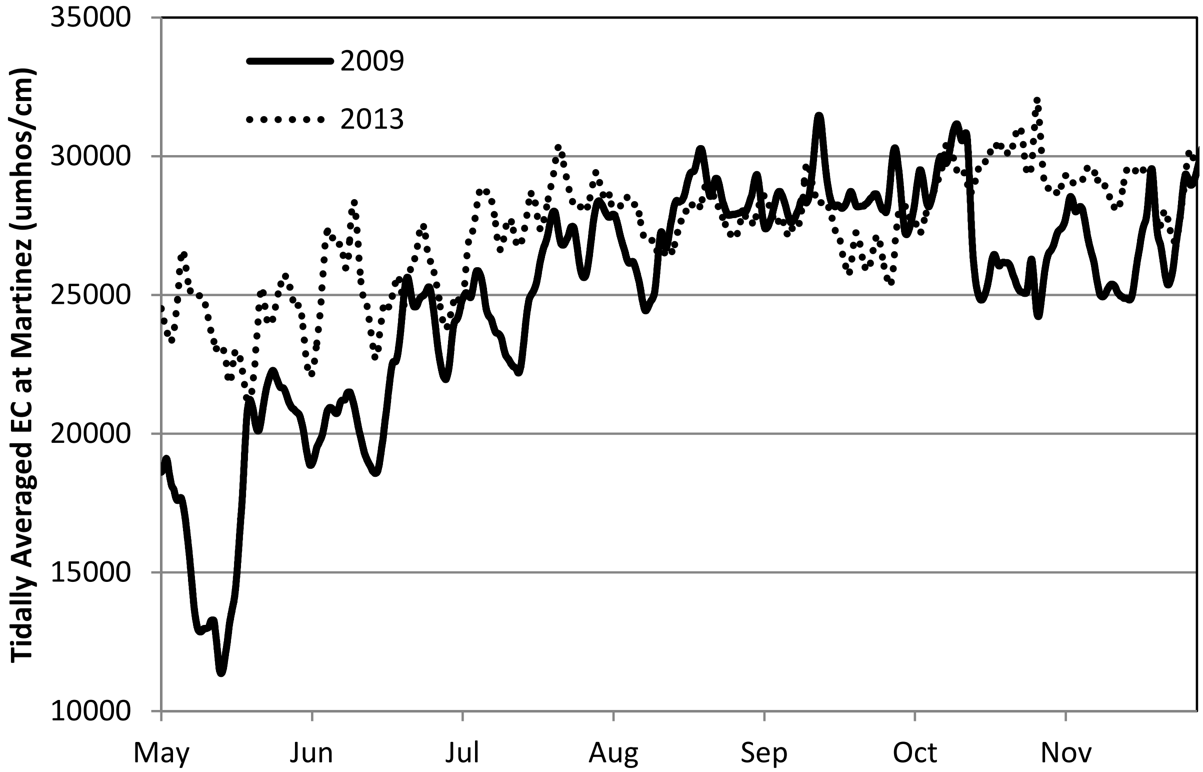

Figure 5 Tidally averaged EC at Martinez for the 2009 and 2013 analysis periods.

Winter Island Restoration Alternatives

Two alternative Winter Island restoration alternatives were considered. For “Alt 1” the existing breach on the west side of the island was enlarged by removing the barge that blocks part of the breach (see Figure 6). A 200 foot breach was added at the south end of the island, connecting to the existing north-south running channel through the marsh plain. “Alt 2” adds another breach at the north end of the island, connecting to the marsh plain channel.

Both alternatives were added to both Base grids for a total of four alternative grids. Grid configuration details are summarized on Table 1. Color contours of model bathymetry for the two alternatives with the Base-1 marsh plain elevations are shown in Figure 7.

Table 1 Summary of model configurations.

Configuration	Marsh Plain Elev	East Breach	South Breach	North Breach
Base-1	From LiDAR data	As exists	No	No
Alt 1	From LiDAR data	Remove barge	200’ wide	No
Alt 2	From LiDAR data	Remove barge	200’ wide	200’ wide
Base-2	LiDAR + 1.6 ft	As exists	No	No
Alt 1	LiDAR + 1.6 ft	Remove barge	200’ wide	No

Alt 2	LiDAR + 1.6 ft	Remove barge	200’ wide	200’ wide

Figure 6 Aerial photograph (source: Google) showing barge blocking east breach on Winter Island.

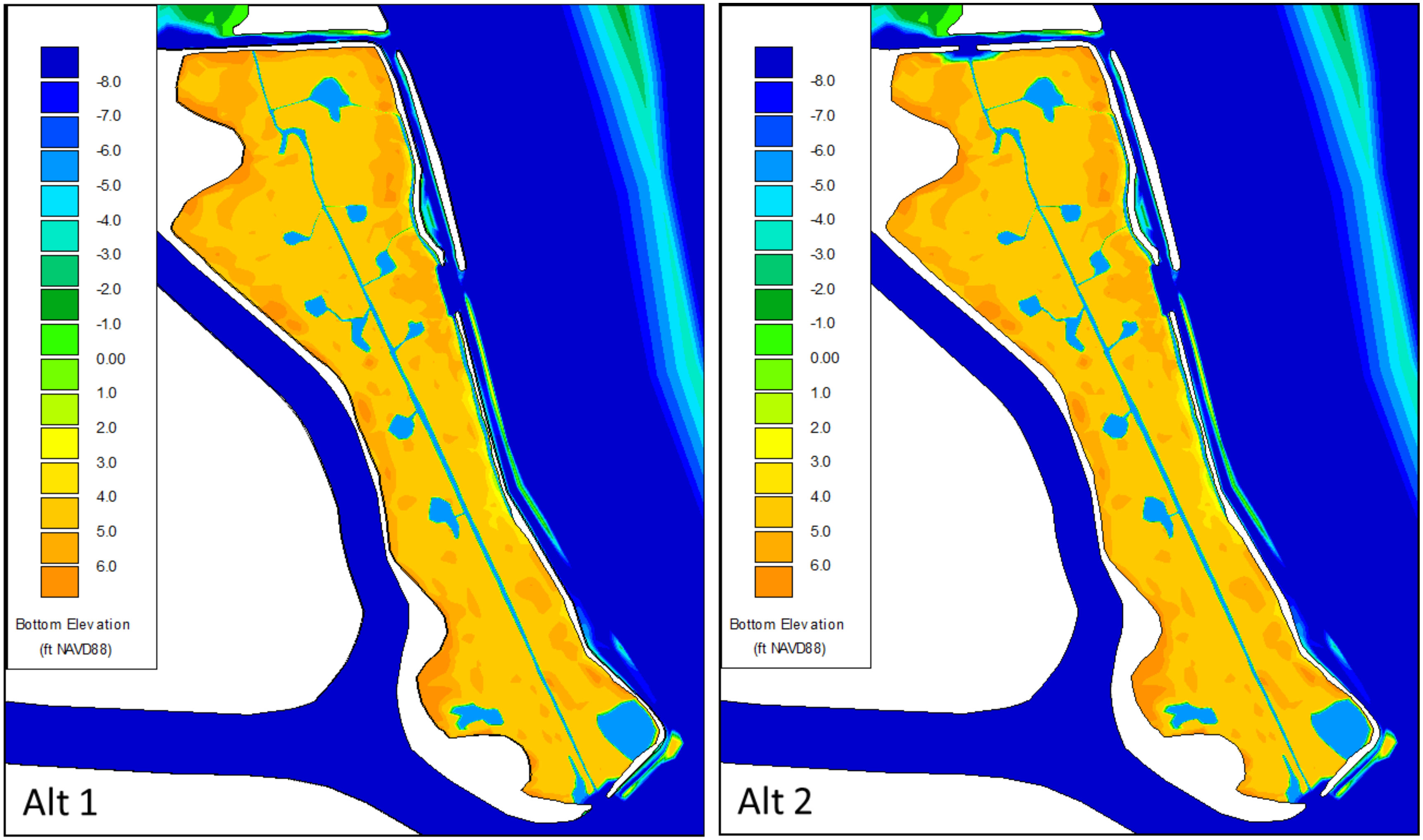

Figure 7 Model bathymetry in the Project vicinity for the Alt 1 and Alt 2 configurations with Base-1 marsh plain elevations.

EC Impact Analysis

Hydrodynamic and EC simulations were performed for January – November of 2009 and 2013 to assess the potential impacts of the restoration alternatives on EC. EC results were analyzed at key locations shown in Figure 8. Monthly averages were computed for May though November of each simulation period and summarized in tabular format (2009 results are tabulated in Table 2 through Table 5; 2013 results are tabulated in Table 6 through Table 9). For the Base-1 and Base-2 (sensitivity) cases, Base EC is tabulated with change and percent change for each alternative. Time series of the monthly averaged Base and percent change results are plotted for a subset of these locations.

From tidally averaged results, EC change and percent change from Base was computed throughout the model network so that color contours could be plotted for any time during the analysis periods. The color contours are displayed so that EC increases are shades of red and decreases are shades of blue. These results are displayed for July 30 for each alternative and each analysis year. For additional comparison, results are shown on September 23, 2009 for the Alt 1 – Base-1 comparison and on September 24, 2013 for the Alt 1 – Base-2 comparison.

In general, the restoration alternatives tend to decrease EC downstream of the Project site and increase EC upstream. The largest increases occur in the San Joaquin River around Antioch, Jersey Point and False River. With the Base-1 configuration, Alt 1 tends to produce slightly larger changes than Alt 2. However, with the Base-2 scenarios the opposite is true. With the lower marsh plain elevations, Base-2 scenarios have a noticeably larger EC impact than the Base-1 scenarios. As an example, during 2013, the Alt 2 Base-2 scenario increases monthly average EC at Antioch by 56.5 µmhos/cm, whereas the Alt 2 Base-1 scenario increase is only 19.5 µmhos/cm at this time.

Impacts at CCWD intakes can be as high as 0.6% for the Base-1 configuration and as high as 0.9% for the Base-2 configuration. Impacts at SWP are slightly lower.

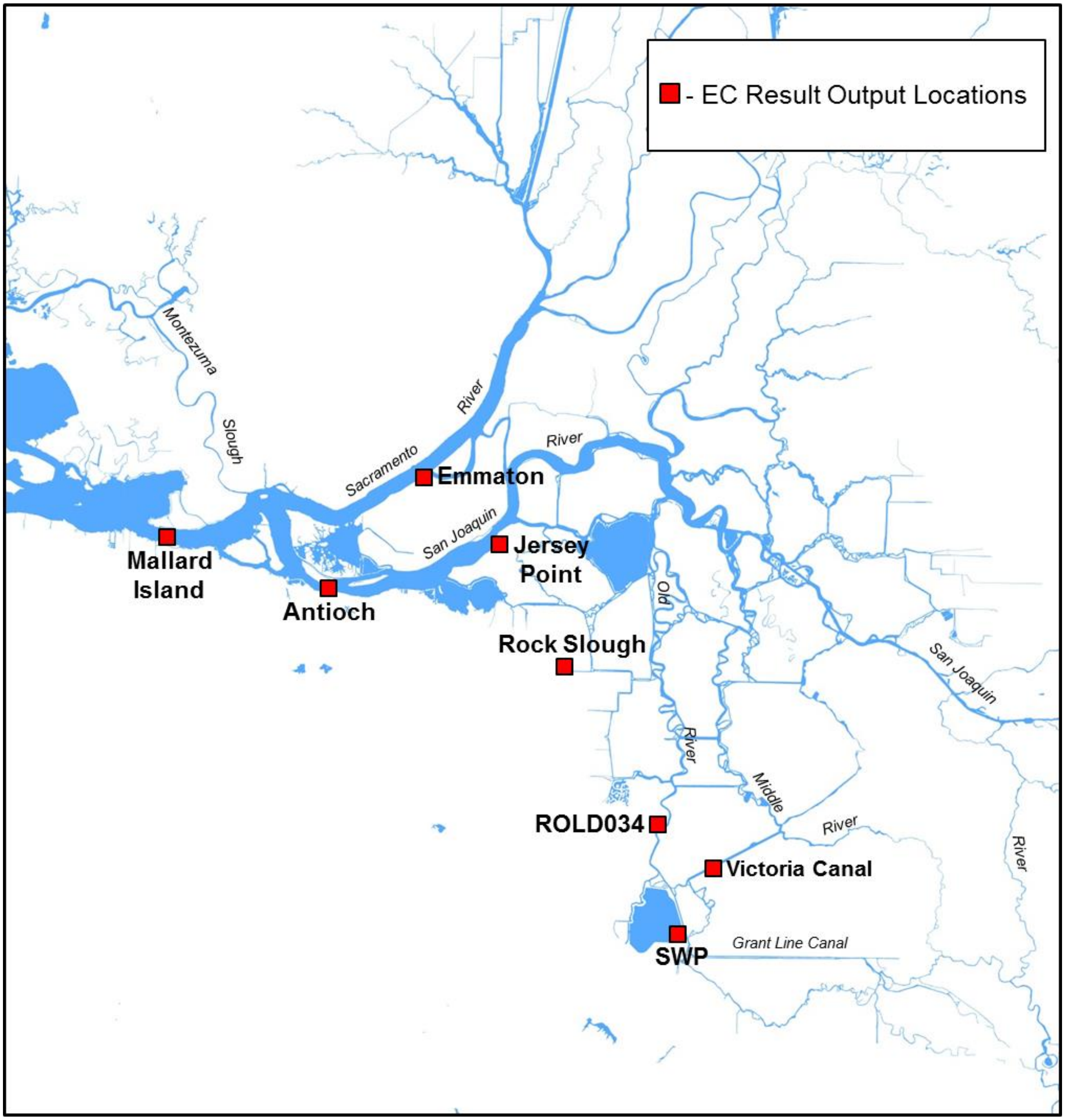

Figure 8 EC result output locations.

2009

EC analysis results for May through November 2009 are provided in the sections below.

Base-1

Results in Table 2 and Table 3, and in Figure 9 through Figure 17 illustrate comparisons between 2009 Base-1 and alternative EC simulation results.

Table 2 Summary of 2009 monthly average Base-1 EC and change from Base-1 EC at key locations for Alt 1 and Alt 2.

	Mallard Is			Emmaton			Antioch			Jersey Pt		
	Base EC µS/cm	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2009	2257	0.31	-0.26	166	0.21	0.19	305	1.56	1.18	204	0.13	0.09
Jun 2009	5546	-0.67	-1.70	367	2.21	2.36	922	8.27	7.39	261	1.18	1.01
Jul 2009	9644	-3.56	-4.42	632	3.85	4.33	2819	18.94	18.35	946	7.77	7.21
Aug 2009	12173	-5.11	-5.64	1131	5.59	6.53	4242	20.39	20.76	1632	10.12	9.54
Sep 2009	13436	-4.40	`-5.16	1631	7.22	8.30	4943	20.95	20.07	1830	10.55	9.53
Oct 2009	12258	-0.94	-1.48	1533	7.53	8.32	4189	22.65	21.61	1469	9.62	8.46
Nov 2009	11202	0.45	-1.38	1271	6.97	7.36	3411	20.74	18.30	1118	8.39	7.38

	Rock Slough			ROLD034			Victoria Canal			SWP		
	Base EC µS/cm	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2009	349	0.03	0.01	329	0.03	0.02	345	0.01	-0.01	350	0.02	0.01
Jun 2009	288	0.06	0.04	292	0.05	0.03	303	0.00	-0.01	352	0.03	0.01
Jul 2009	362	1.90	1.76	337	1.79	1.65	241	0.59	0.54	306	1.36	1.25
Aug 2009	752	4.51	4.27	667	3.95	3.75	377	1.79	1.66	568	3.21	3.03
Sep 2009	895	4.73	4.53	775	4.05	3.85	454	1.85	1.75	669	3.30	3.13
Oct 2009	862	4.39	4.04	705	3.43	3.15	464	1.53	1.41	628	2.76	2.53
Nov 2009	659	3.56	3.24	563	2.87	2.61	410	1.36	1.25	539	1.94	1.77

Table 3 Summary of 2009 monthly average Base-1 EC and percent change from Base-1 EC at key locations for Alt 1 and Alt 2.

	Mallard Is			Emmaton			Antioch			Jersey Pt		
	Base EC µS/cm	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2009	2257	0.01%	-0.01%	166	0.13%	0.11%	305	0.51%	0.38%	204	0.06%	0.04%
Jun 2009	5546	-0.01%	-0.03%	367	0.60%	0.64%	922	0.89%	0.79%	261	0.45%	0.39%
Jul 2009	9644	-0.04%	-0.05%	632	0.61%	0.68%	2819	0.67%	0.65%	946	0.81%	0.76%
Aug 2009	12173	-0.04%	-0.05%	1131	0.49%	0.57%	4242	0.48%	0.49%	1632	0.62%	0.58%
Sep 2009	13436	-0.03%	-0.04%	1631	0.44%	0.51%	4943	0.42%	0.40%	1830	0.57%	0.52%
Oct 2009	12258	-0.01%	-0.01%	1533	0.49%	0.54%	4189	0.54%	0.51%	1469	0.65%	0.57%
Nov 2009	11202	0.00%	-0.01%	1271	0.55%	0.58%	3411	0.60%	0.53%	1118	0.75%	0.66%

	Rock Slough			ROLD034			Victoria Canal			SWP		
	Base EC µS/cm	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2009	349	0.01%	0.00%	329	0.01%	0.00%	345	0.00%	0.00%	350	0.00%	0.00%
Jun 2009	288	0.02%	0.02%	292	0.02%	0.01%	303	0.00%	0.00%	352	0.01%	0.00%
Jul 2009	362	0.52%	0.48%	337	0.53%	0.49%	241	0.25%	0.22%	306	0.44%	0.41%
Aug 2009	752	0.60%	0.57%	667	0.59%	0.56%	377	0.47%	0.44%	568	0.56%	0.53%
Sep 2009	895	0.53%	0.50%	775	0.52%	0.49%	454	0.41%	0.38%	669	0.49%	0.47%
Oct 2009	862	0.51%	0.47%	705	0.48%	0.44%	464	0.33%	0.30%	628	0.44%	0.40%
Nov 2009	659	0.54%	0.49%	563	0.51%	0.46%	410	0.33%	0.30%	539	0.36%	0.33%

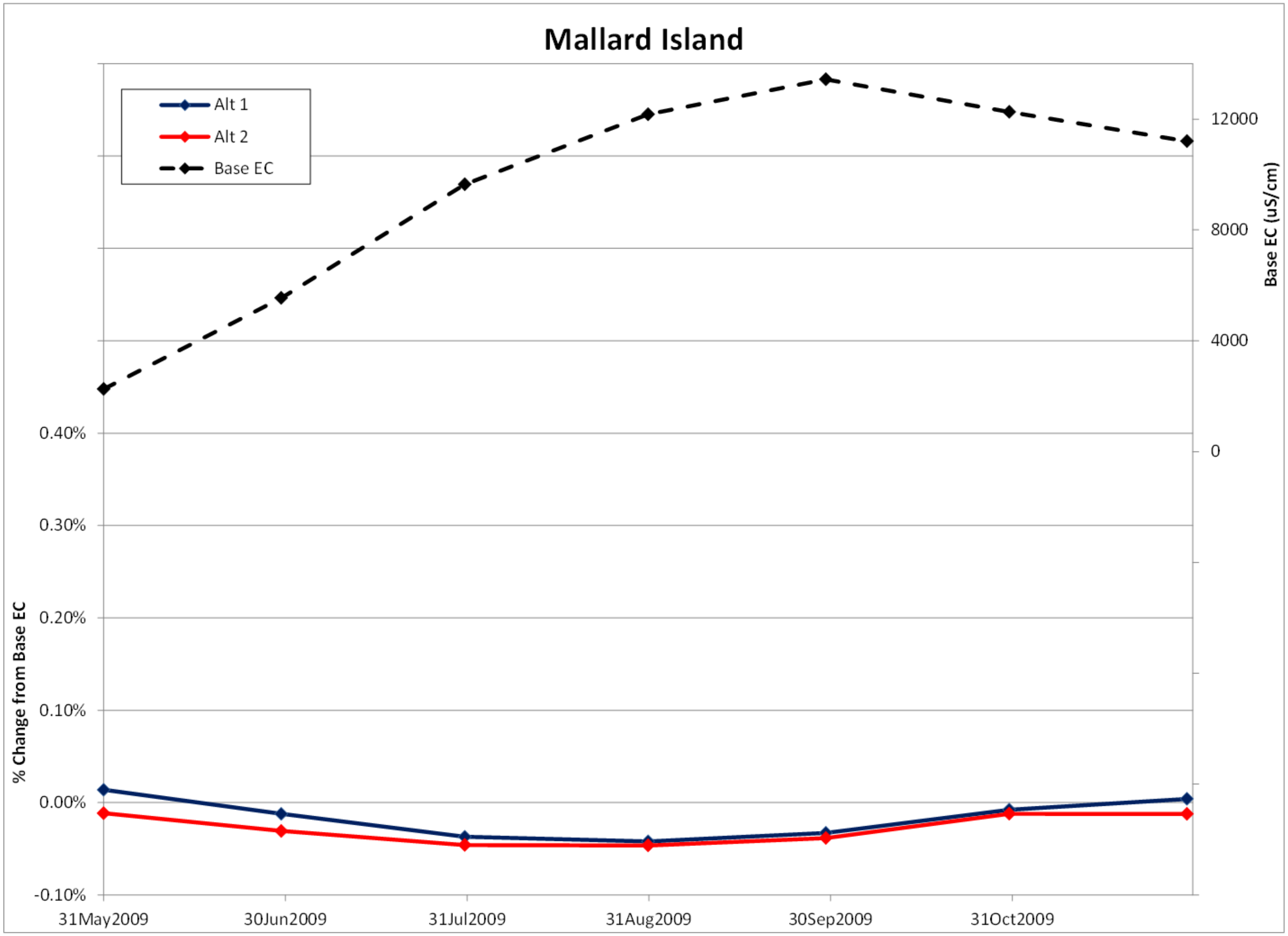
Mallard Island
Alt 1
Alt 2
Base EC
0.40%
0.30%
0.20%
0.10%
0.00%
-0.10%
% Change from Base EC
12000
8000
4000
0
Base EC (uS/cm)
31May2009
30Jun2009
31Jul2009
31Aug2009
30Sep2009
31Oct2009

Figure 9 Time series of Alt 1 and Alt 2 monthly averaged % change from Base-1 EC plotted with Base-1 EC at Mallard Island for the 2009 analysis period.

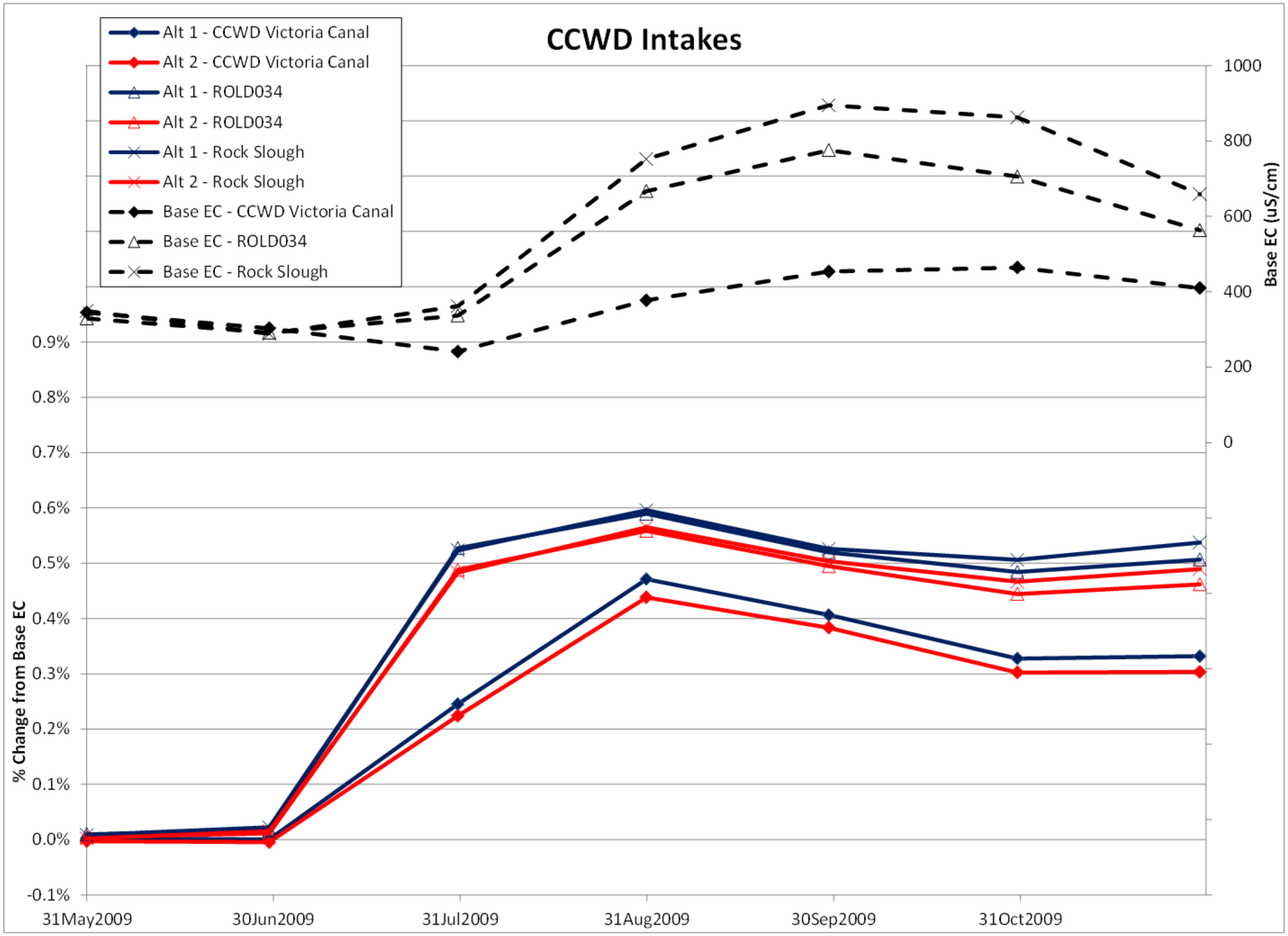

Figure 10 Time series of Alt 1 and Alt 2 monthly averaged % change from Base-1 EC plotted with Base-1 EC at the Contra Costa Water District intakes for the 2009 analysis period.

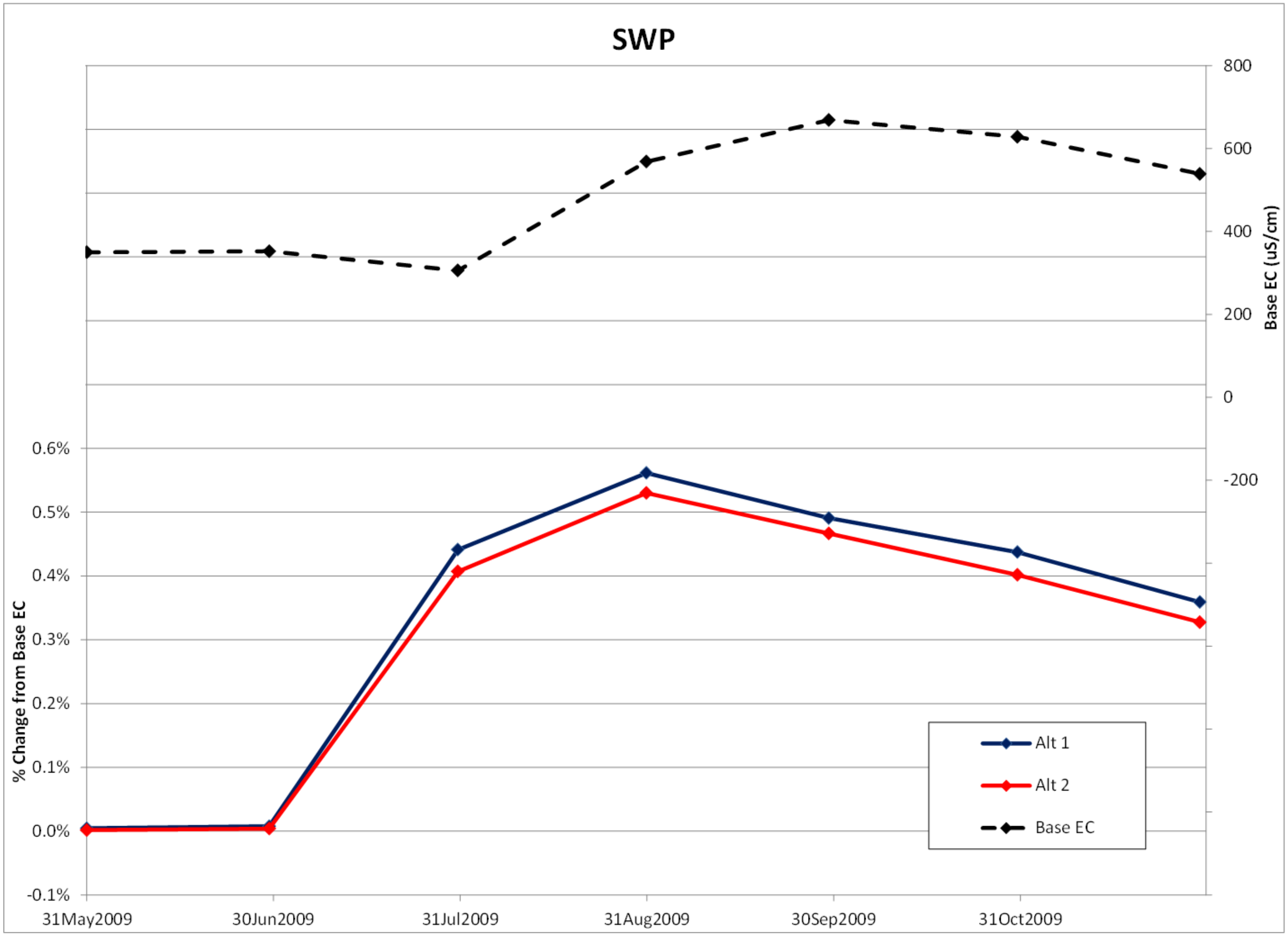

Figure 11 Time series of Alt 1 and Alt 2 monthly averaged % change from Base-1 EC plotted with Base-1 EC at SWP for the 2009 analysis period.

Alt 1 color contour plots – 2009 Base-1

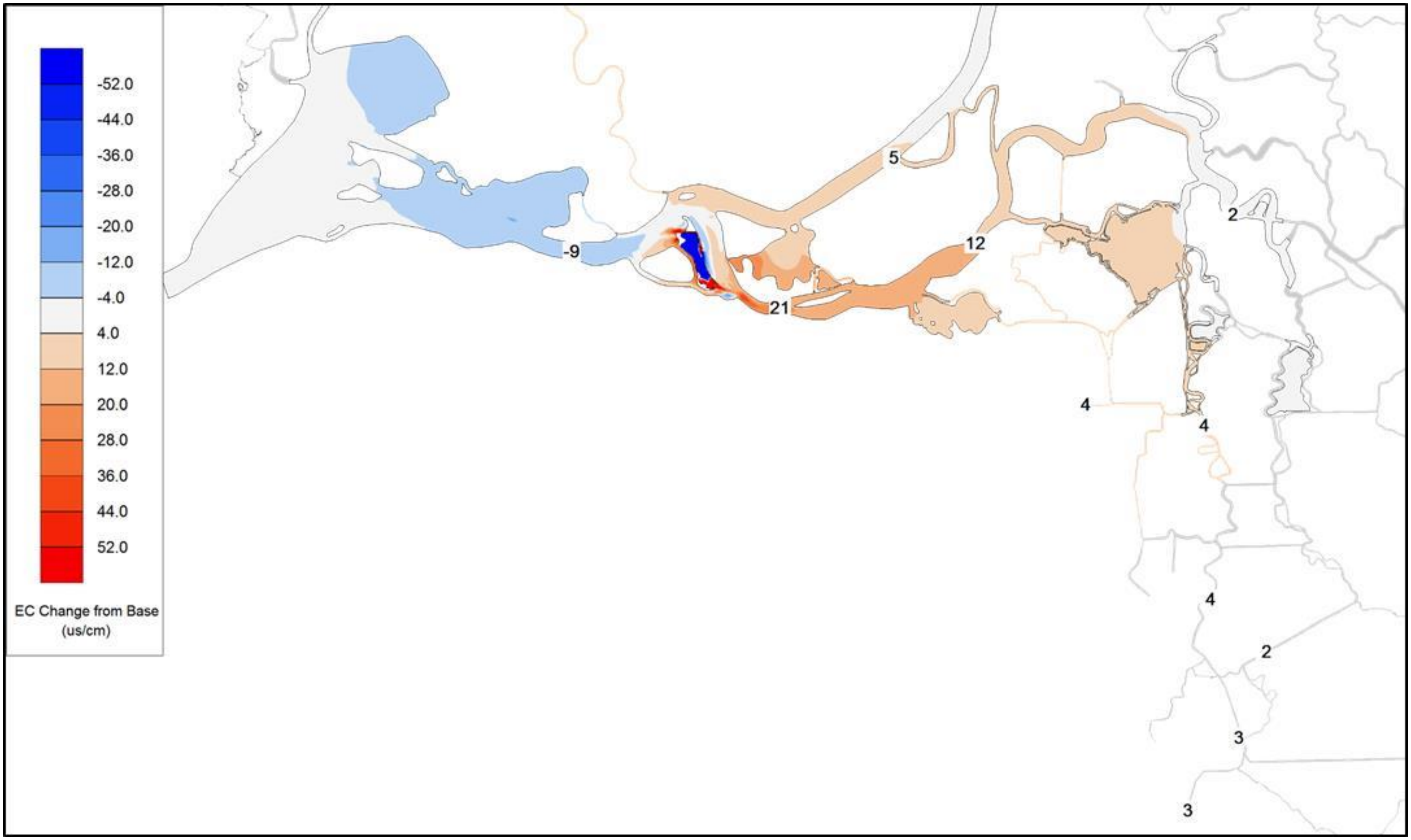

Figure 12 Alt 1: tidally averaged change from Base-1 EC on July 30, 2009.

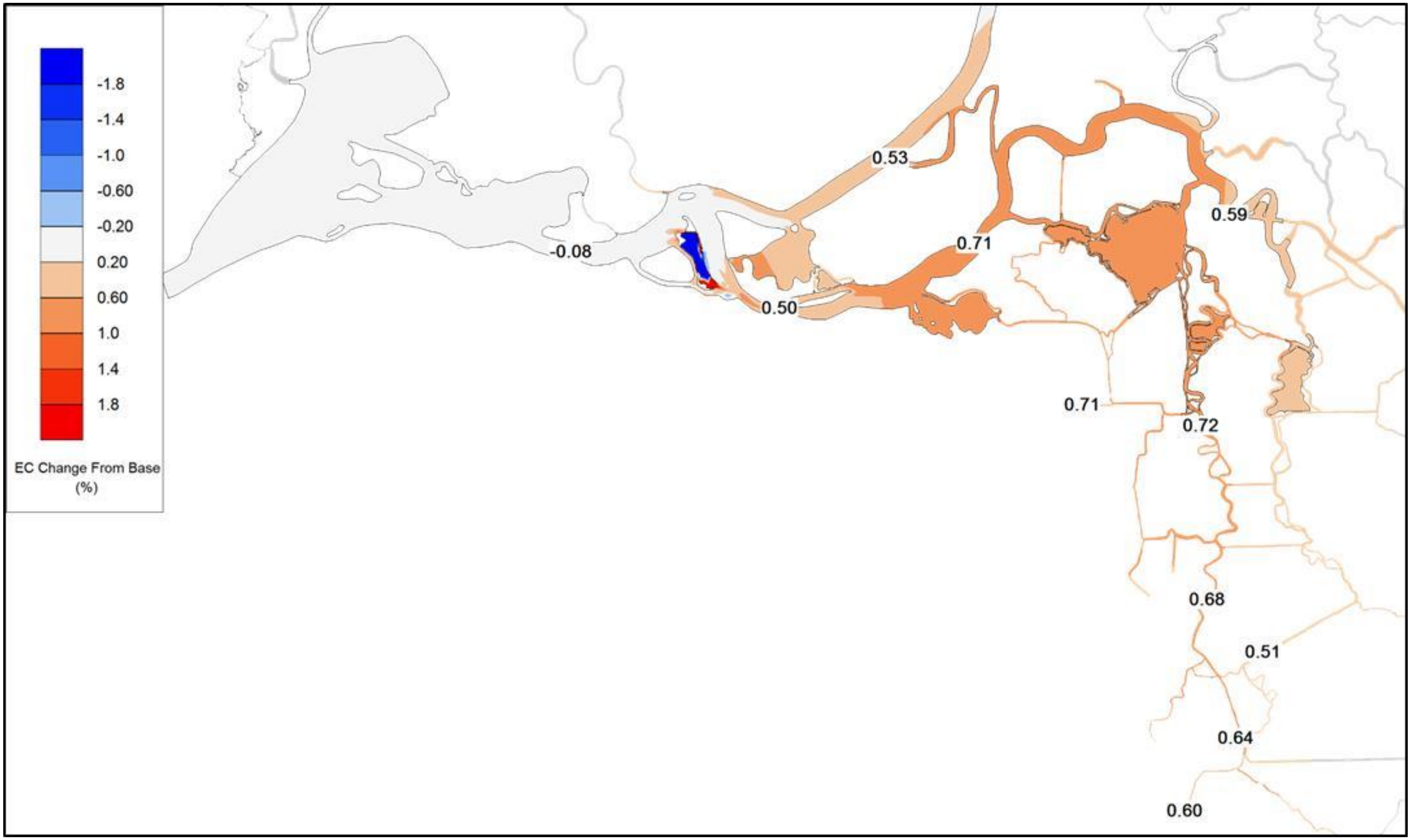

Figure 13 Alt 1: tidally averaged percent change from Base-1 EC on July 30, 2009.

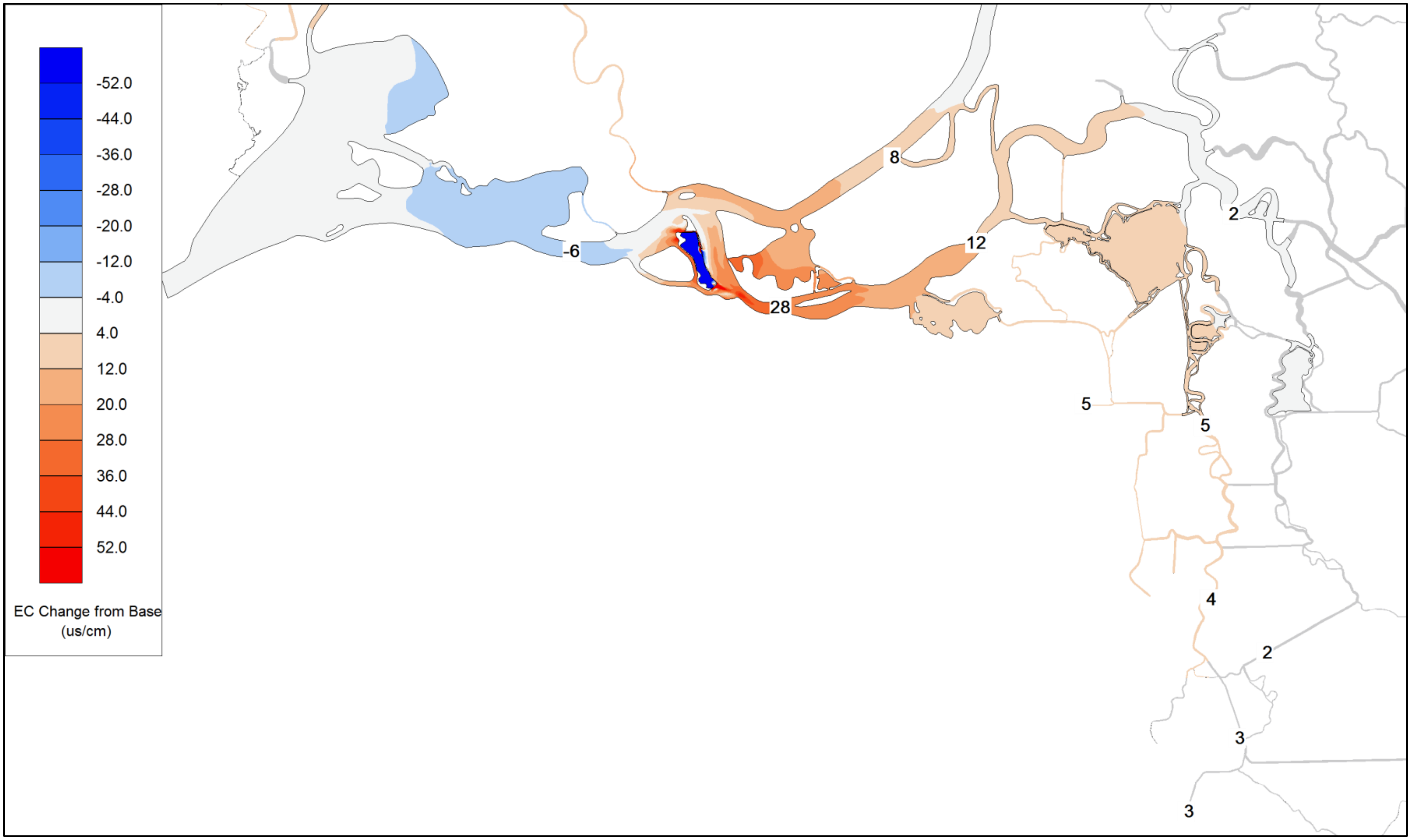

Figure 14 Alt 1: tidally averaged change from Base-1 EC on September 23, 2009.

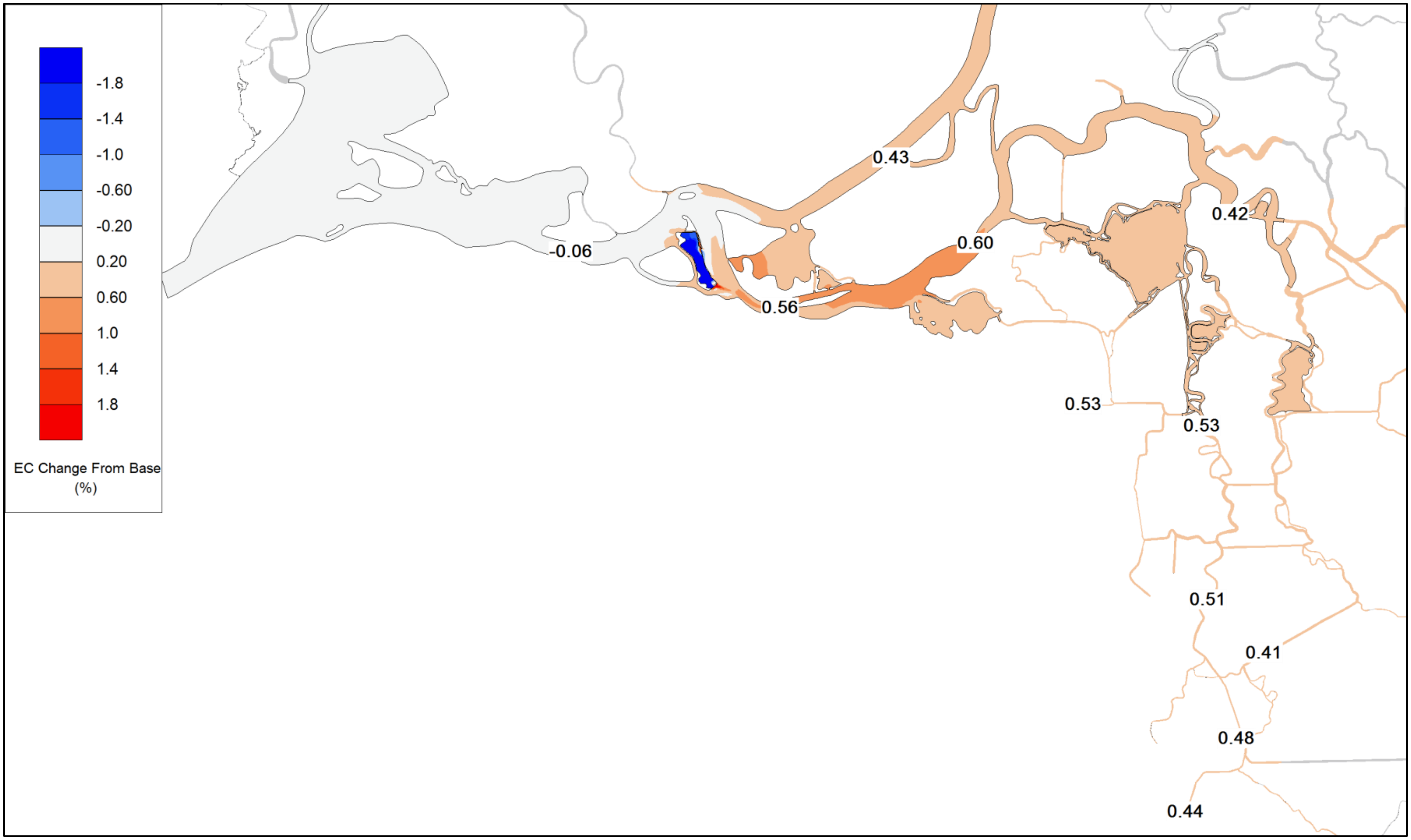

Figure 15 Alt 1: tidally averaged percent change from Base-1 EC on September 23, 2009.

Alt 2 color contour plots – 2009 Base-1

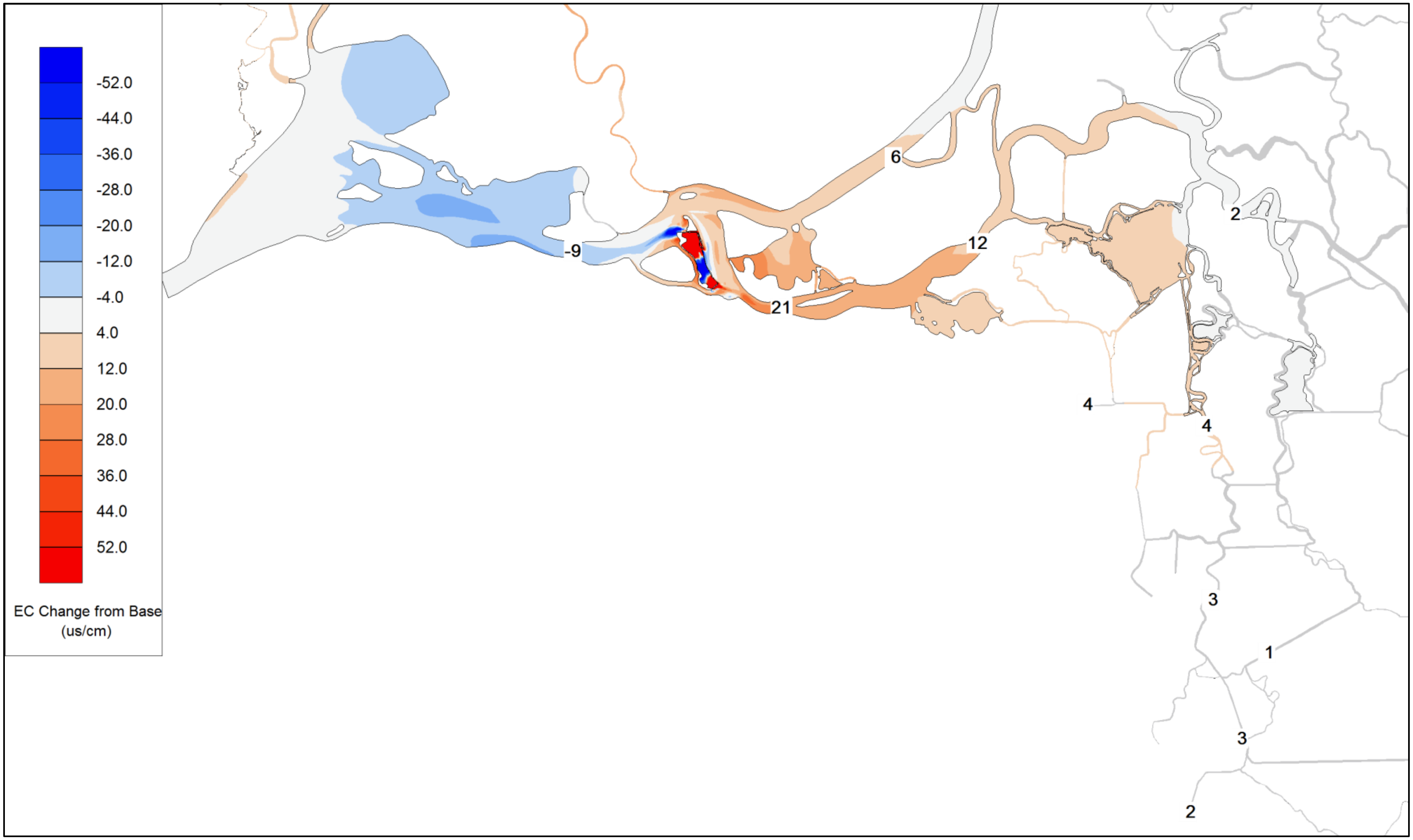

Figure 16 Alt 2: tidally averaged change from Base-1 EC on July 30, 2009.

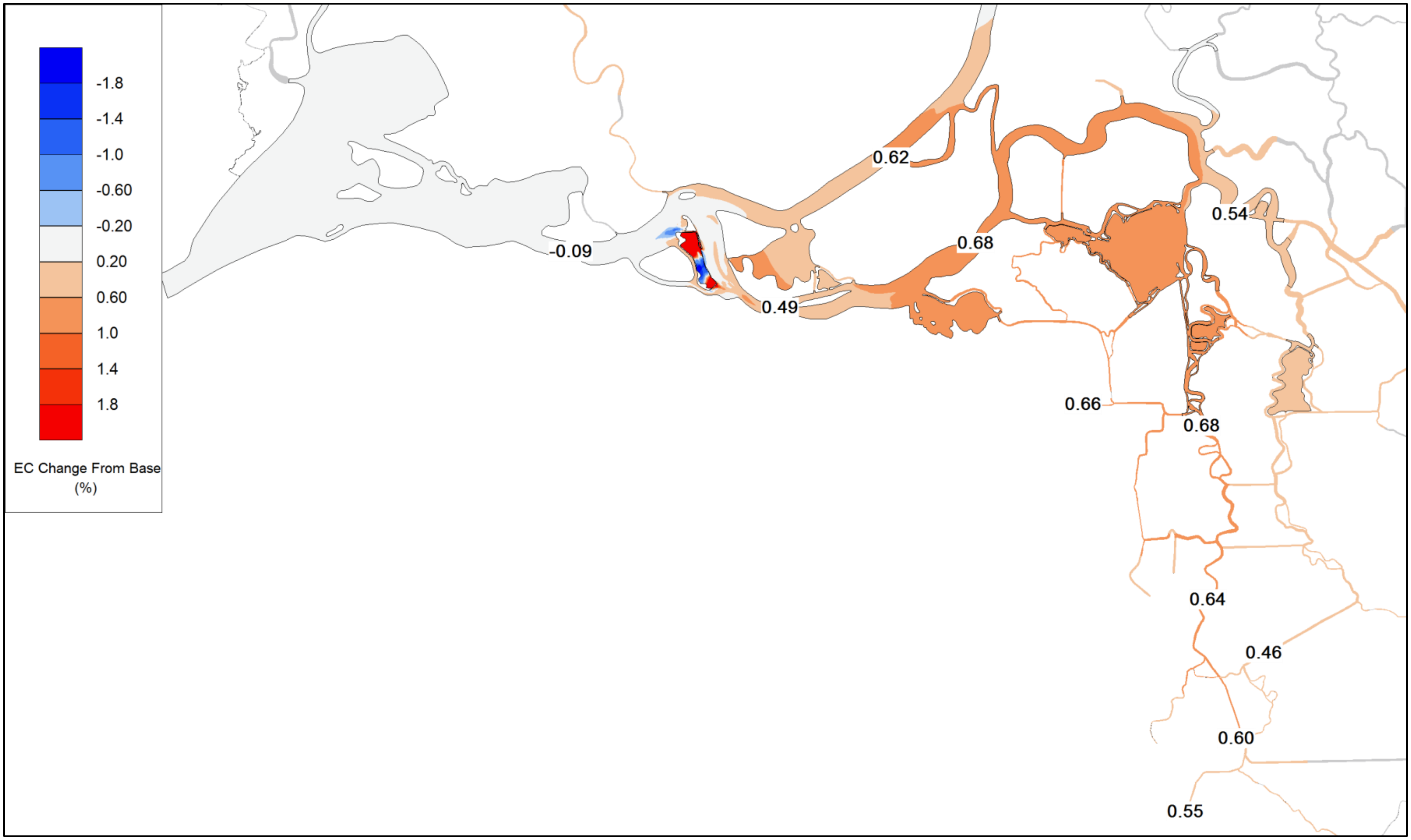

Figure 17 Alt 2: tidally averaged percent change from Base-1 EC on July 30, 2009.

Base-2

Results in Table 4 and Table 5, and in Figure 18 through Figure 24 illustrate comparisons between 2009 Base-2 and alternative EC simulation results.

Table 4 Summary of 2009 monthly average Base-2 EC and change from Base-2 EC at key locations for Alt 1 and Alt 2.

	Mallard Is			Emmaton			Antioch			Jersey Pt		
	Base EC µS/cm	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2009	2260	0.88	0.49	167	0.27	0.22	306	2.29	1.72	204	0.21	0.15
Jun 2009	5551	-0.78	-0.78	368	2.75	2.79	928	11.85	10.50	262	1.99	1.74
Jul 2009	9647	-4.76	-4.40	633	4.48	5.17	2831	24.71	25.20	950	11.12	10.81
Aug 2009	12175	-6.24	-5.47	1131	7.49	9.01	4257	29.86	32.54	1637	15.03	15.35
Sep 2009	13438	-5.25	-4.81	1631	10.87	13.07	4959	34.86	38.45	1836	16.70	17.92
Oct 2009	12262	-1.19	0.22	1534	11.54	13.55	4207	38.09	40.77	1475	16.01	16.82
Nov 2009	11206	-0.37	-1.35	1272	10.42	11.95	3425	33.91	34.58	1122	13.65	13.88

	Rock Slough			ROLD034			Victoria Canal			SWP		
	Base EC µS/cm	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2009	349	0.06	0.03	329	0.04	0.02	345	-0.01	-0.03	350	0.02	0.00
Jun 2009	288	0.09	0.07	292	0.05	0.03	303	-0.03	-0.05	352	-0.01	-0.03
Jul 2009	363	2.70	2.59	338	2.53	2.43	241	0.86	0.82	306	1.93	1.85
Aug 2009	754	6.10	6.13	669	5.42	5.48	378	2.49	2.47	570	4.42	4.45
Sep 2009	897	6.84	7.21	778	5.96	6.34	455	2.80	2.93	670	4.89	5.18
Oct 2009	865	6.65	7.23	707	5.29	5.77	465	2.41	2.64	630	4.28	4.67
Nov 2009	661	5.69	6.03	565	4.64	4.92	410	2.28	2.45	540	3.15	3.35

Table 5 Summary of 2009 monthly average Base-2 EC and percent change from Base-2 EC at key locations for Alt 1 and Alt 2.

	Mallard Is			Emmaton			Antioch			Jersey Pt		
	Base EC µS/cm	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2009	2260	0.04%	0.02%	167	0.16%	0.13%	306	0.74%	0.56%	204	0.10%	0.07%
Jun 2009	5551	-0.01%	-0.01%	368	0.74%	0.75%	928	1.26%	1.12%	262	0.76%	0.66%
Jul 2009	9647	-0.05%	-0.05%	633	0.70%	0.81%	2831	0.87%	0.88%	950	1.16%	1.12%
Aug 2009	12175	-0.05%	-0.04%	1131	0.66%	0.79%	4257	0.70%	0.76%	1637	0.91%	0.93%
Sep 2009	13438	-0.04%	-0.04%	1631	0.66%	0.79%	4959	0.70%	0.77%	1836	0.90%	0.97%
Oct 2009	12262	-0.01%	0.00%	1534	0.75%	0.88%	4207	0.90%	0.96%	1475	1.07%	1.13%
Nov 2009	11206	0.00%	-0.01%	1272	0.81%	0.93%	3425	0.98%	1.00%	1122	1.20%	1.22%

	Rock Slough			ROLD034			Victoria Canal			SWP		
	Base EC µS/cm	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2009	349	0.02%	0.01%	329	0.01%	0.01%	345	0.00%	-0.01%	350	0.00%	0.00%
Jun 2009	288	0.03%	0.02%	292	0.02%	0.01%	303	-0.01%	-0.02%	352	0.00%	-0.01%
Jul 2009	363	0.74%	0.71%	338	0.74%	0.71%	241	0.35%	0.34%	306	0.63%	0.60%
Aug 2009	754	0.80%	0.81%	669	0.80%	0.81%	378	0.65%	0.65%	570	0.77%	0.77%
Sep 2009	897	0.76%	0.80%	778	0.76%	0.81%	455	0.61%	0.64%	670	0.72%	0.77%
Oct 2009	865	0.76%	0.83%	707	0.74%	0.81%	465	0.52%	0.56%	630	0.68%	0.74%
Nov 2009	661	0.85%	0.91%	565	0.82%	0.86%	410	0.55%	0.59%	540	0.58%	0.62%

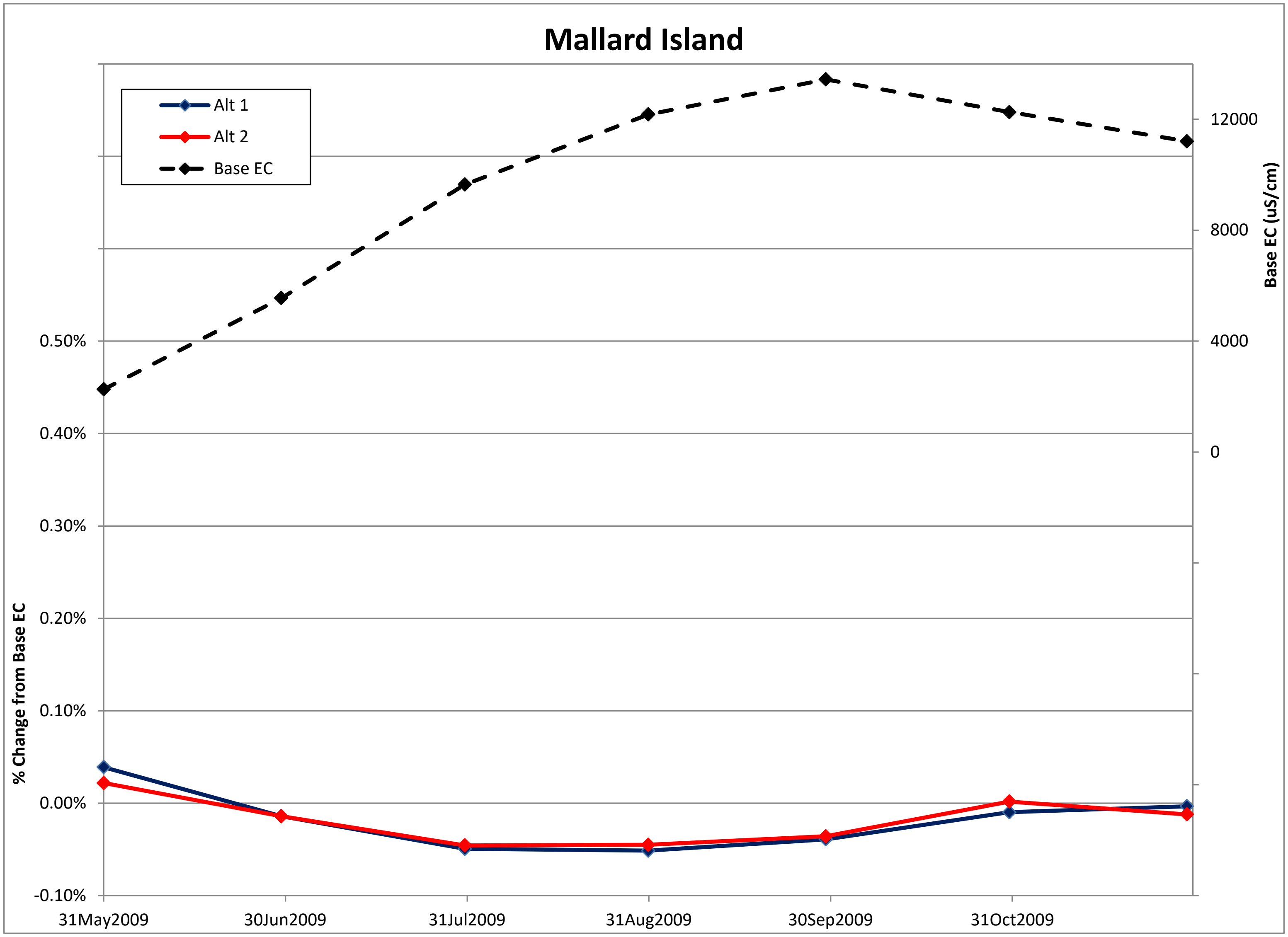

Figure 18 Time series of Alt 1 and Alt 2 monthly averaged % change from Base-2 EC plotted with Base-2 EC at Mallard Island for the 2009 analysis period.

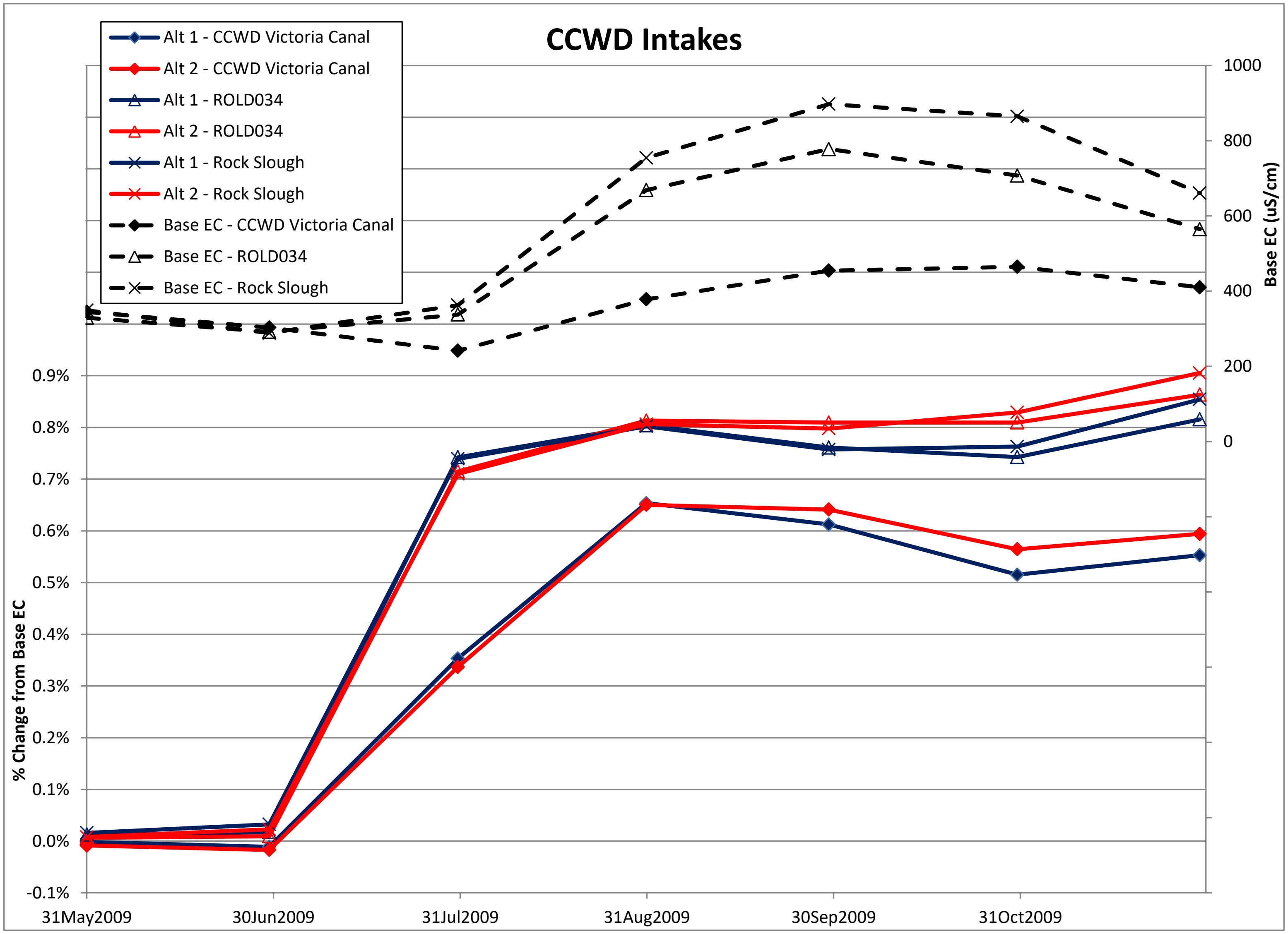

Figure 19 Time series of Alt 1 and Alt 2 monthly averaged % change from Base-2 EC plotted with Base-2 EC at the Contra Costa Water District intakes for the 2009 analysis period.

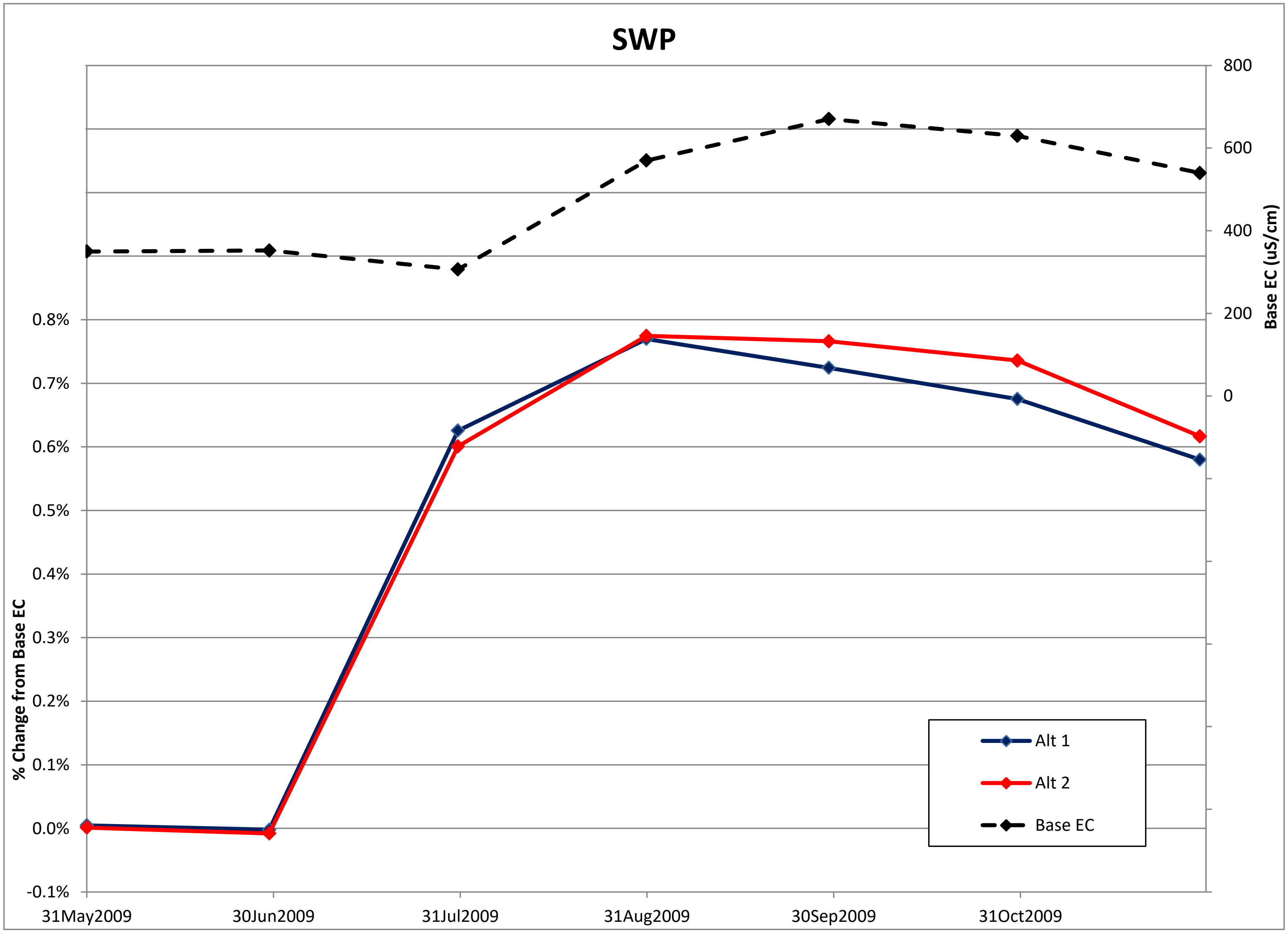

Figure 20 Time series of Alt 1 and Alt 2 monthly averaged % change from Base-2 EC plotted with Base-2 EC at SWP for the 2009 analysis period.

Alt 1 color contour plots – 2009 Base-2

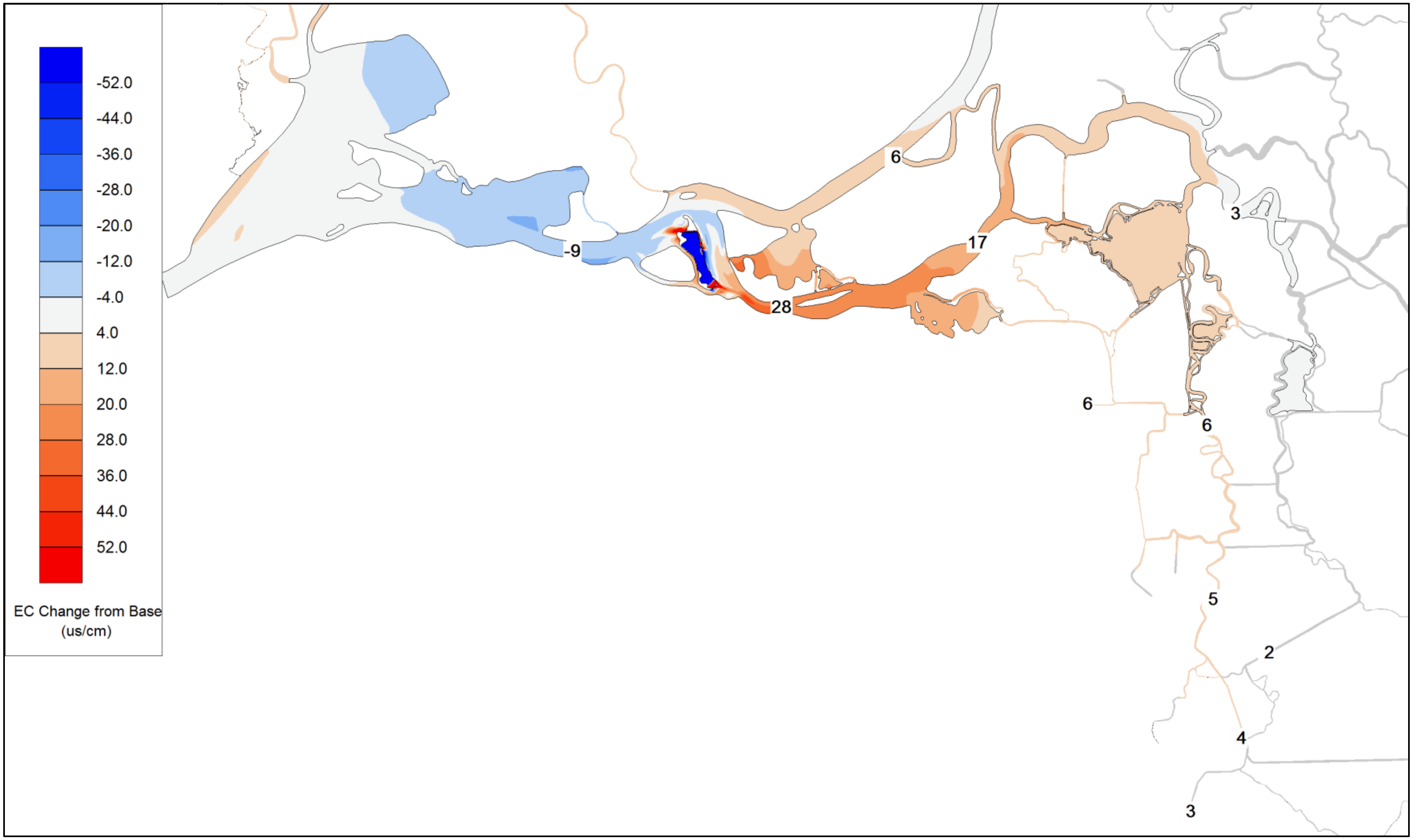

Figure 21 Alt 1: tidally averaged change from Base-2 EC on July 30, 2009.

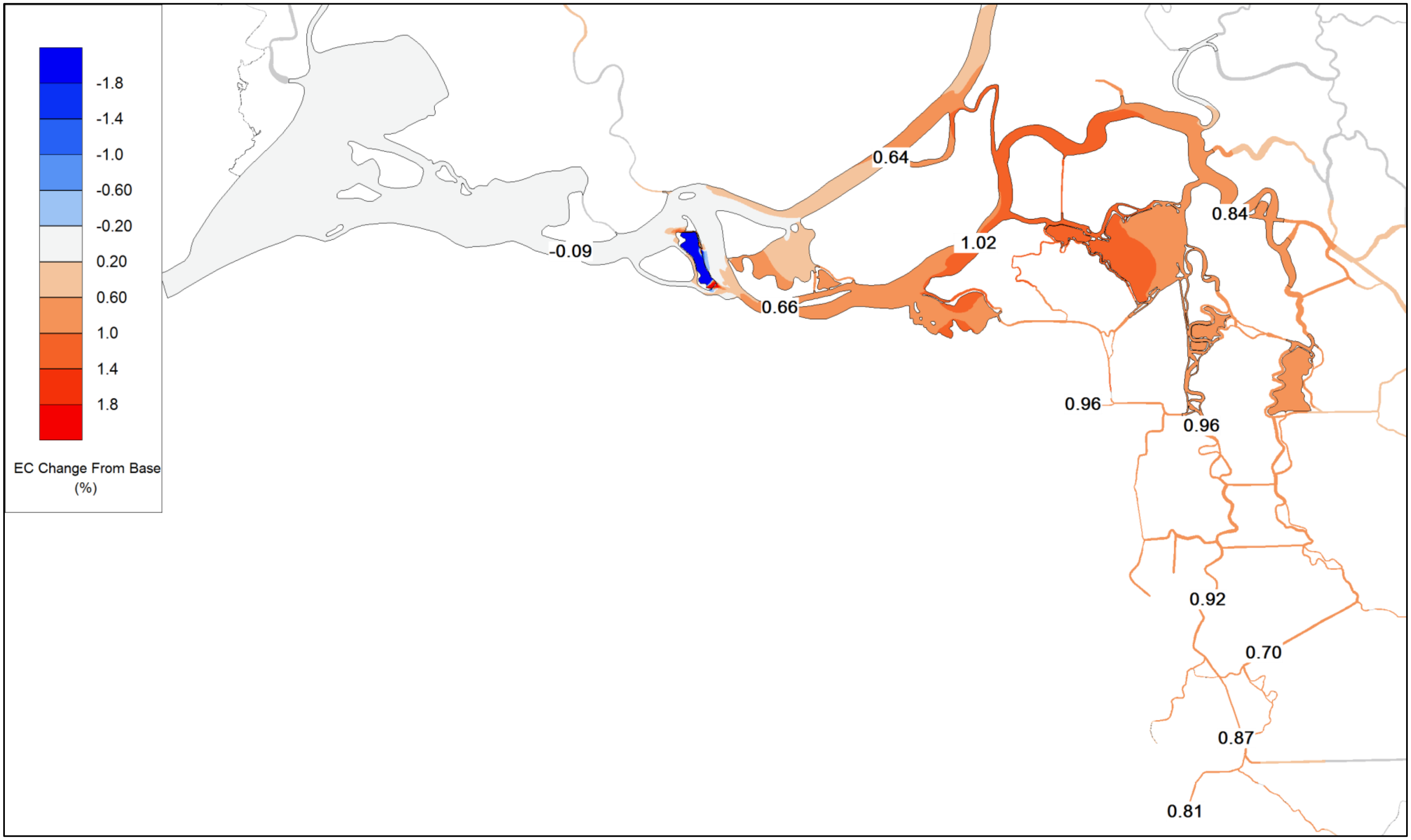

Figure 22 Alt 1: tidally averaged percent change from Base-2 EC on July 30, 2009.

Alt 2 color contour plots – 2009 Base-2

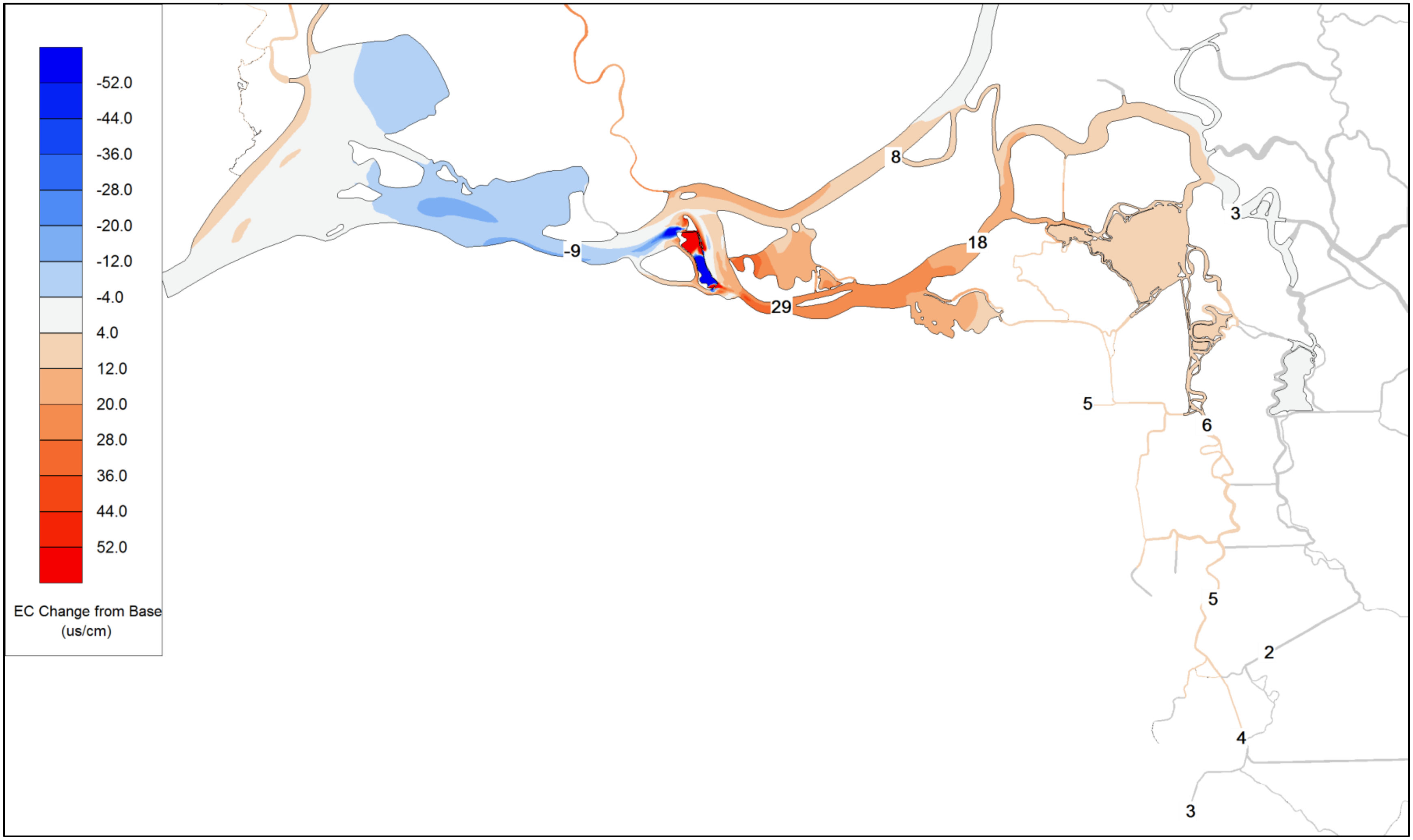

Figure 23 Alt 2: tidally averaged change from Base-2 EC on July 30, 2009.

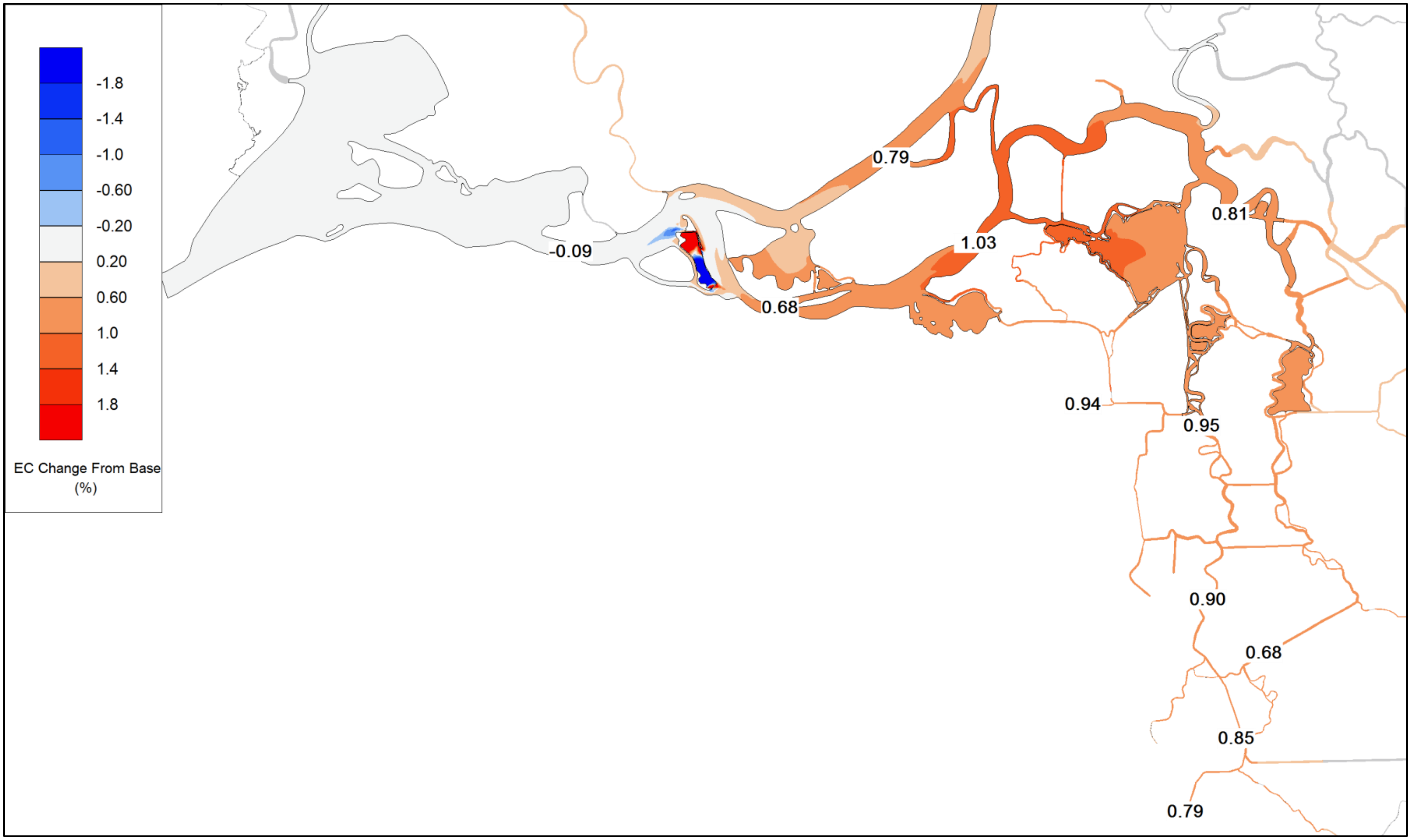

Figure 24 Alt 2: tidally averaged percent change from Base-2 EC on July 30, 2009.

2013

Base-1

Results in Table 6 and Table 7, and in Figure 25 through Figure 31 illustrate comparisons between 2013 Base-1 and alternative EC simulation results.

Table 6 Summary of 2013 monthly average Base-1 EC and change from Base-1 EC at key locations for Alt 1 and Alt 2.

	Mallard Is			Emmaton			Antioch			Jersey Pt		
	Base EC µS/cm	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2013	6275	0.43	-2.20	324	1.29	1.27	924	6.99	5.54	304	1.04	0.83
Jun 2013	7884	0.23	-1.66	511	3.15	3.27	1586	13.86	12.30	431	2.98	2.51
Jul 2013	10485	-3.89	-5.91	607	3.50	3.98	2869	19.52	19.14	938	7.48	7.00
Aug 2013	10679	-3.87	-6.27	594	3.17	3.31	3202	18.54	16.74	1265	8.93	7.91
Sep 2013	9604	-1.11	-4.69	582	2.61	2.63	2531	14.76	12.36	1036	6.49	5.42
Oct 2013	12160	-3.05	-7.33	1295	5.91	6.31	3428	18.92	15.30	945	6.54	5.36
Nov 2013	13571	-4.82	-8.21	1361	7.29	7.70	4133	23.16	19.50	1165	9.05	7.41

	Rock Slough			ROLD034			Victoria Canal			SWP		
	Base EC µS/cm	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2013	362	0.10	0.06	351	0.07	0.04	361	0.03	0.00	330	0.04	0.02
Jun 2013	328	0.52	0.44	319	0.40	0.33	309	0.15	0.12	343	0.28	0.24
Jul 2013	402	2.09	1.93	366	1.89	1.75	260	0.61	0.55	332	1.44	1.33
Aug 2013	633	3.90	3.65	553	3.34	3.10	330	1.33	1.23	487	2.73	2.53
Sep 2013	698	3.86	3.41	588	3.10	2.73	378	1.39	1.22	531	2.61	2.30

Oct 2013	512	2.35	2.02	452	1.87	1.62	358	0.82	0.71	432	1.48	1.28
Nov 2013	560	2.93	2.53	518	2.49	2.14	416	1.19	1.04	505	1.80	1.56

Table 7 Summary of 2013 monthly average Base-1 EC and percent change from Base-1 EC at key locations for Alt 1 and Alt 2.

	Mallard Is			Emmaton			Antioch			Jersey Pt		
	Base EC µS/cm	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2013	6275	0.01%	-0.04%	324	0.40%	0.39%	924	0.75%	0.60%	304	0.34%	0.27%
Jun 2013	7884	0.00%	-0.02%	511	0.61%	0.64%	1586	0.87%	0.77%	431	0.69%	0.58%
Jul 2013	10485	-0.04%	-0.06%	607	0.57%	0.65%	2869	0.68%	0.66%	938	0.79%	0.74%
Aug 2013	10679	-0.04%	-0.06%	594	0.53%	0.55%	3202	0.58%	0.52%	1265	0.70%	0.62%
Sep 2013	9604	-0.01%	-0.05%	582	0.45%	0.45%	2531	0.58%	0.49%	1036	0.62%	0.52%
Oct 2013	12160	-0.03%	-0.06%	1295	0.45%	0.48%	3428	0.55%	0.44%	945	0.69%	0.56%
Nov 2013	13571	-0.04%	-0.06%	1361	0.53%	0.56%	4133	0.56%	0.47%	1165	0.77%	0.63%

	Rock Slough			ROLD034			Victoria Canal			SWP		
	Base EC µS/cm	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2013	362	0.03%	0.02%	351	0.02%	0.01%	361	0.01%	0.00%	330	0.01%	0.01%
Jun 2013	328	0.16%	0.13%	319	0.13%	0.10%	309	0.05%	0.04%	343	0.08%	0.07%
Jul 2013	402	0.52%	0.48%	366	0.51%	0.48%	260	0.23%	0.21%	332	0.43%	0.40%
Aug 2013	633	0.61%	0.57%	553	0.60%	0.56%	330	0.40%	0.37%	487	0.56%	0.52%
Sep 2013	698	0.55%	0.49%	588	0.52%	0.46%	378	0.37%	0.32%	531	0.49%	0.43%
Oct 2013	512	0.46%	0.39%	452	0.41%	0.36%	358	0.23%	0.20%	432	0.34%	0.30%
Nov 2013	560	0.52%	0.45%	518	0.48%	0.41%	416	0.28%	0.25%	505	0.35%	0.31%

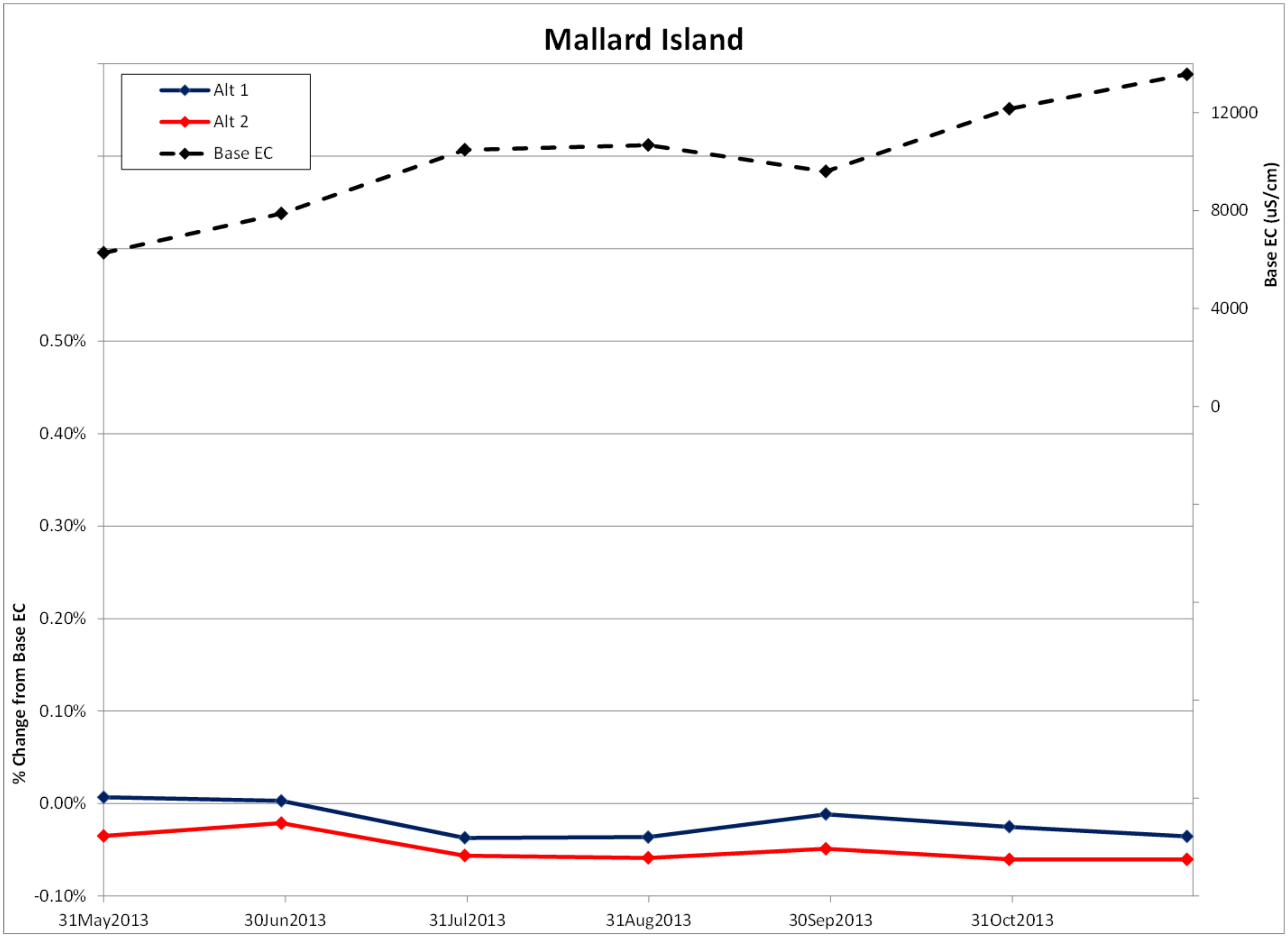
Mallard Island
Alt 1
Alt 2
Base EC
% Change from Base EC
Base EC (uS/cm)
0.50%
0.40%
0.30%
0.20%
0.10%
0.00%
-0.10%
12000
8000
4000
0
31May2013
30Jun2013
31Jul2013
31Aug2013
30Sep2013
31Oct2013

Figure 25 Time series of Alt 1 and Alt 2 monthly averaged % change from Base-1 EC plotted with Base-1 EC at Mallard Island for the 2013 analysis period.

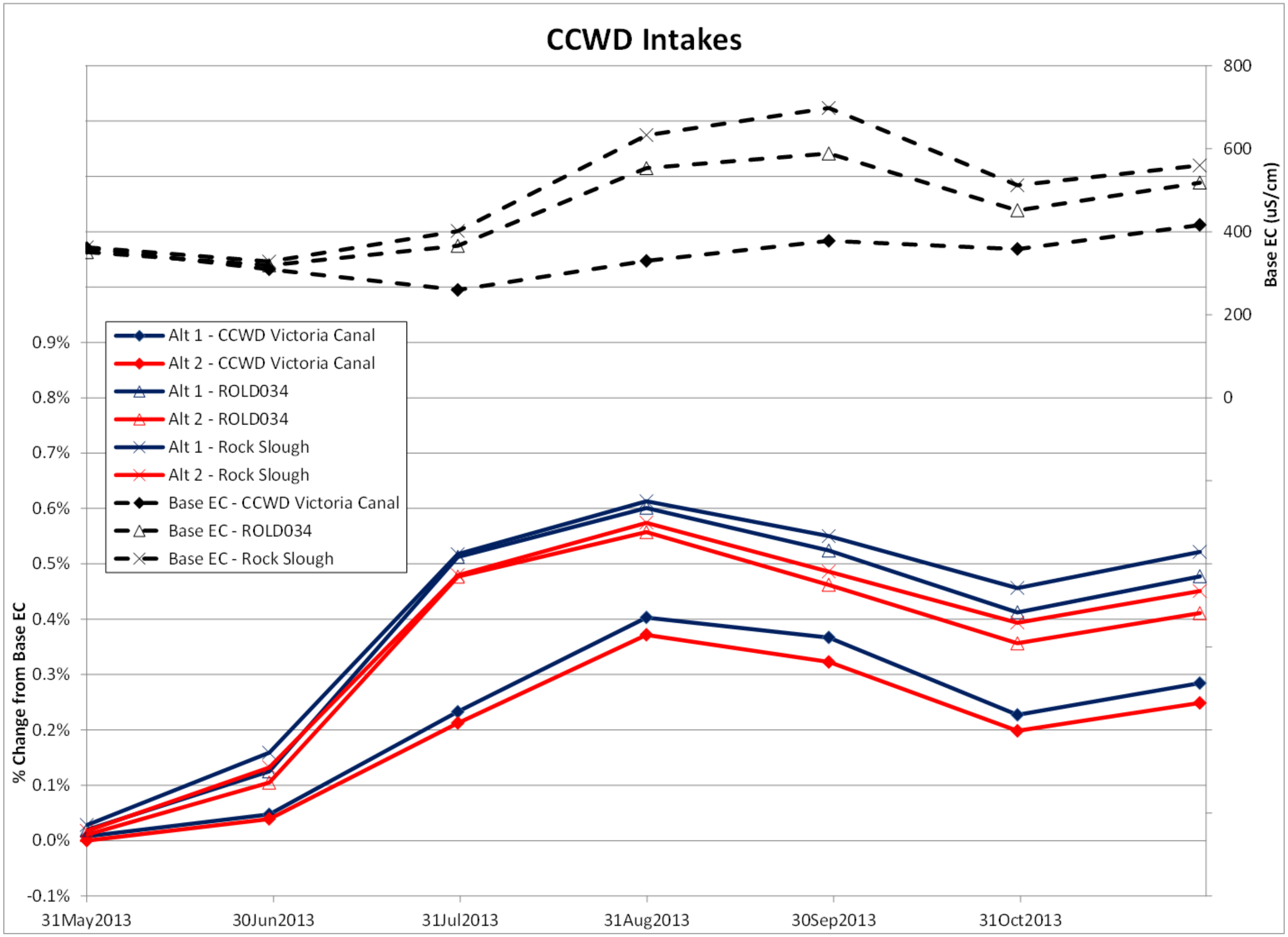

Figure 26 Time series of Alt 1 and Alt 2 monthly averaged % change from Base-1 EC plotted with Base-1 EC at the Contra Costa Water District intakes for the 2013 analysis period.

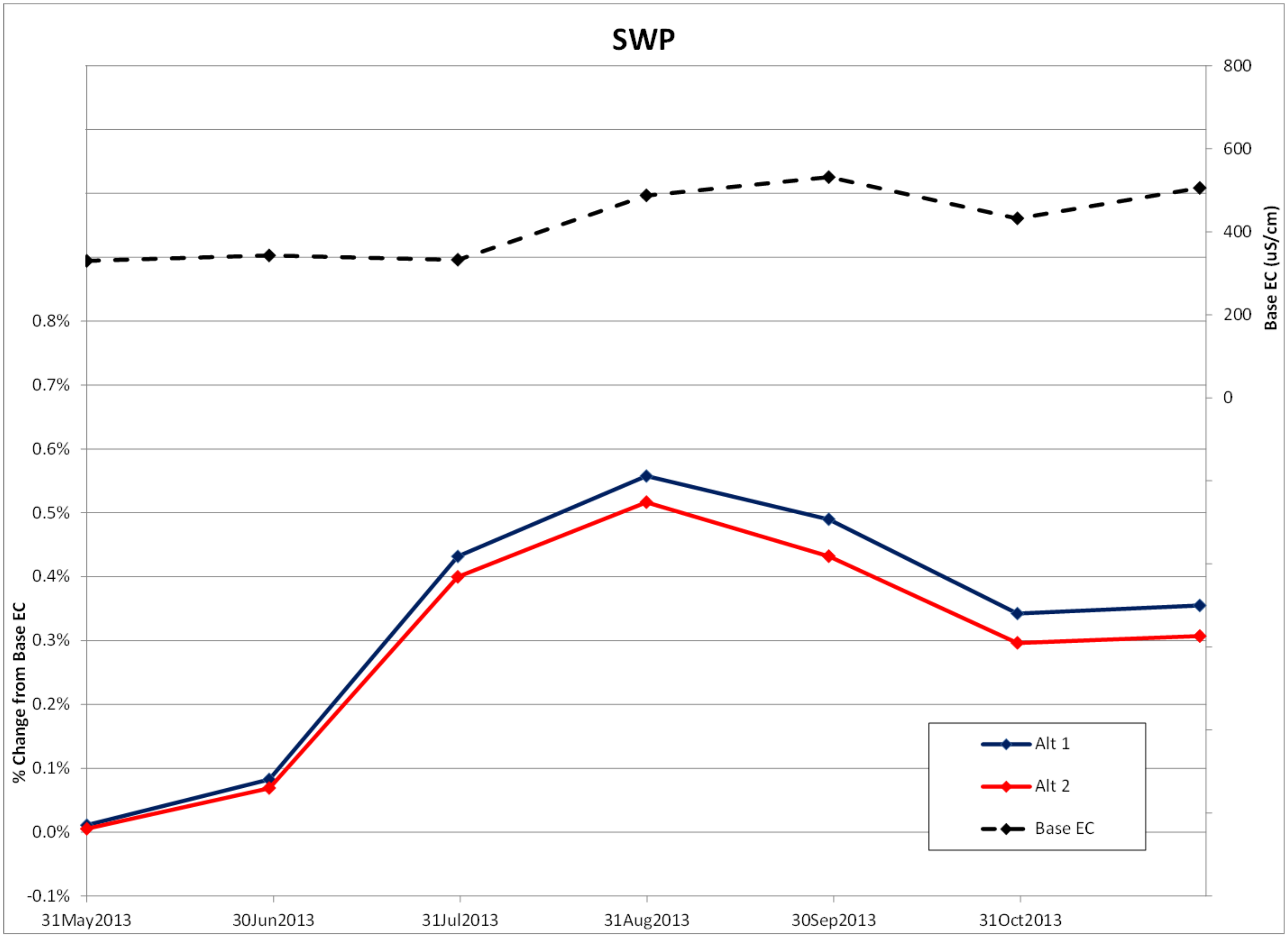

Figure 27 Time series of Alt 1 and Alt 2 monthly averaged % change from Base-1 EC plotted with Base-1 EC at SWP for the 2013 analysis period.

Alt 1 color contour plots – 2013 Base-1

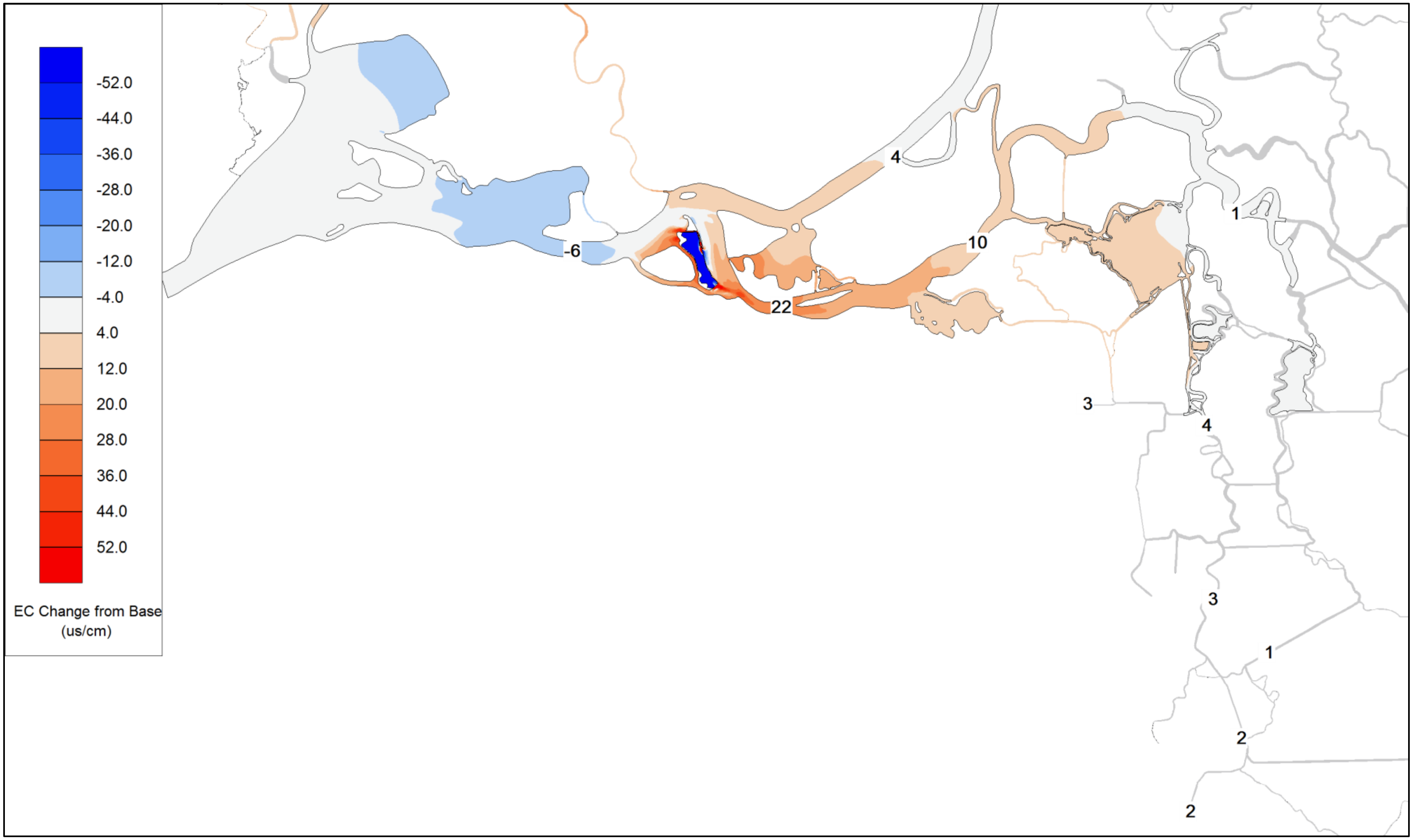

Figure 28 Alt 1: tidally averaged change from Base-1 EC on July 30, 2013.

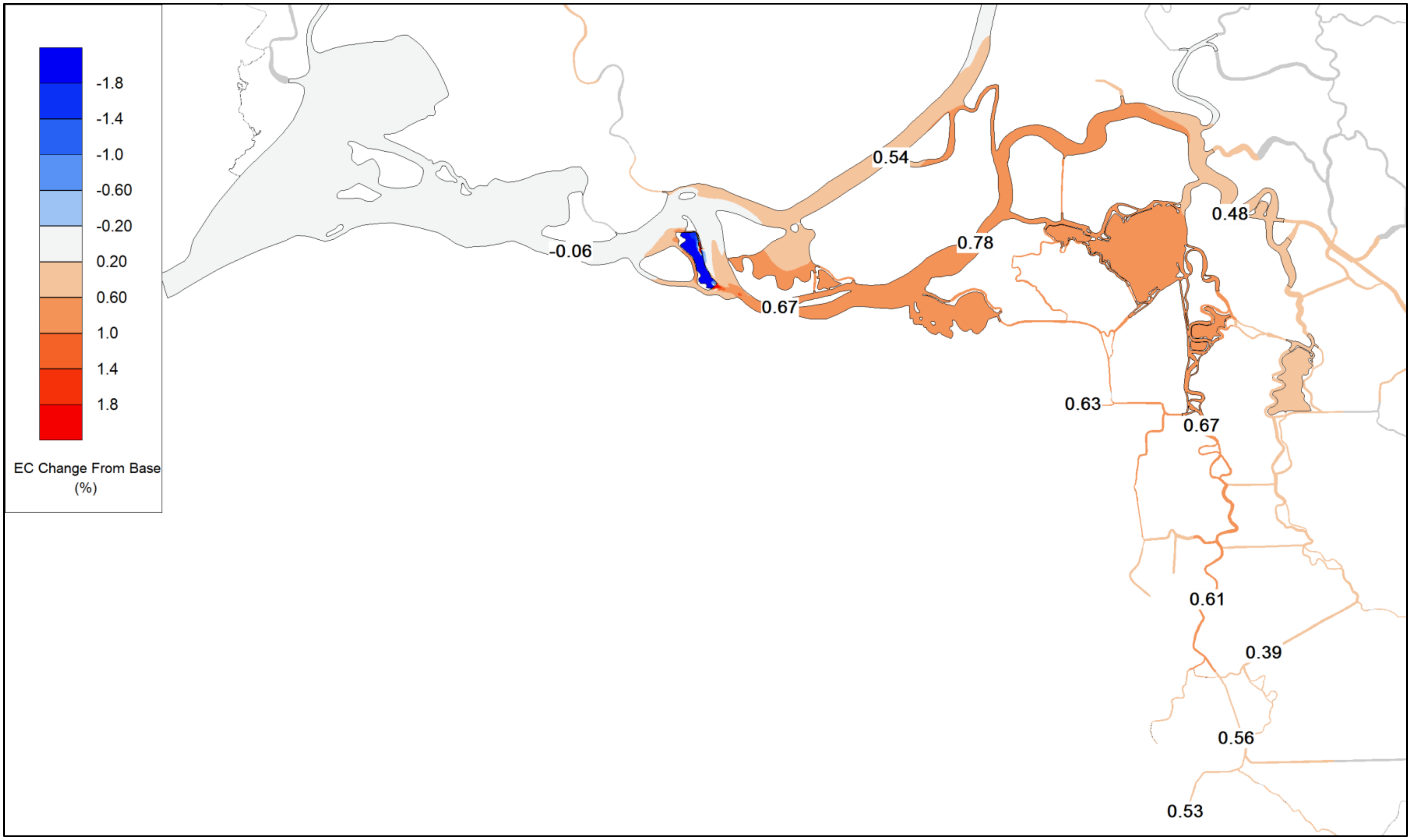

Figure 29 Alt 1: tidally averaged percent change from Base-1 EC on July 30, 2013.

Alt 2 color contour plots – 2013 Base-1

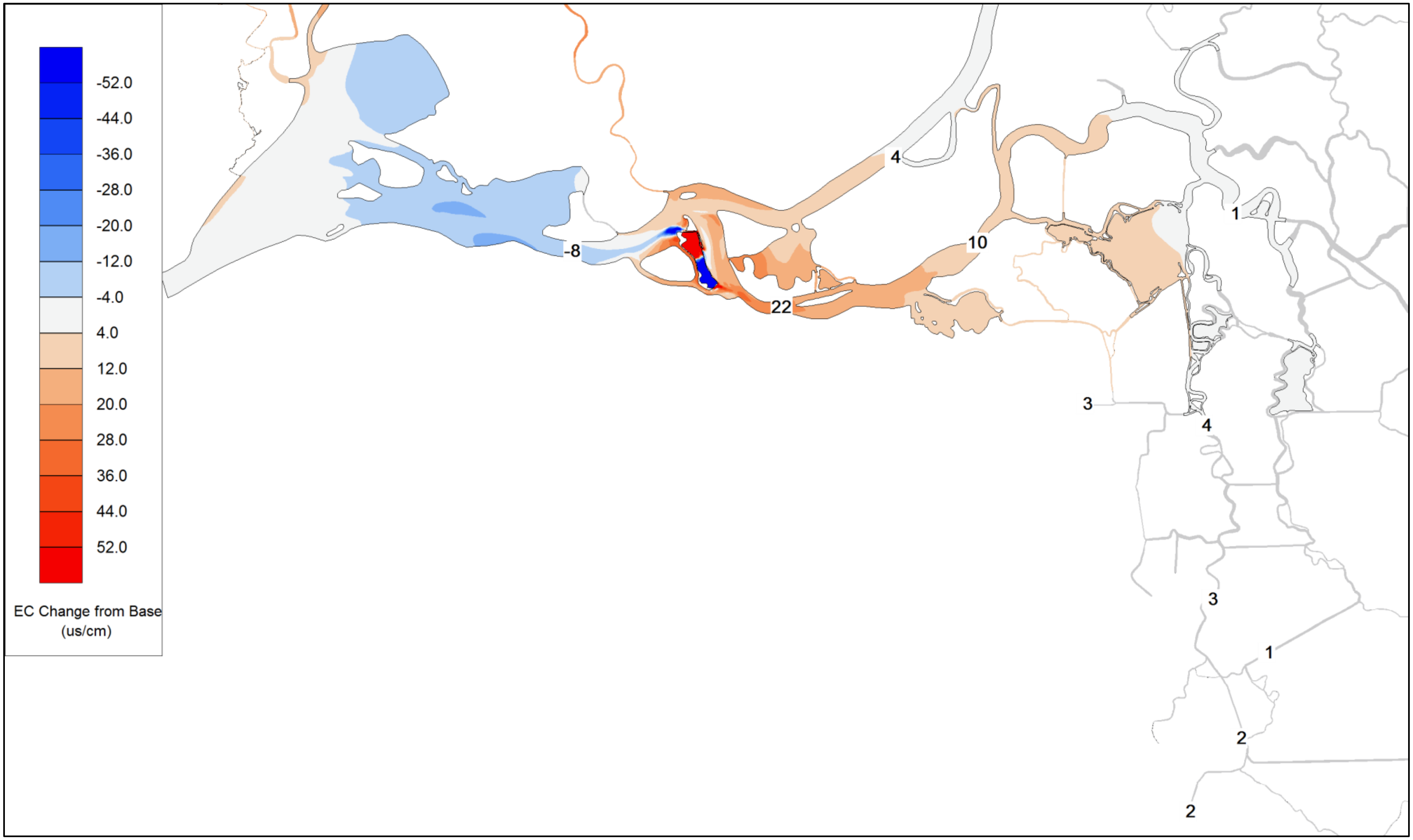

Figure 30 Alt 2: tidally averaged change from Base-1 EC on July 30, 2013.

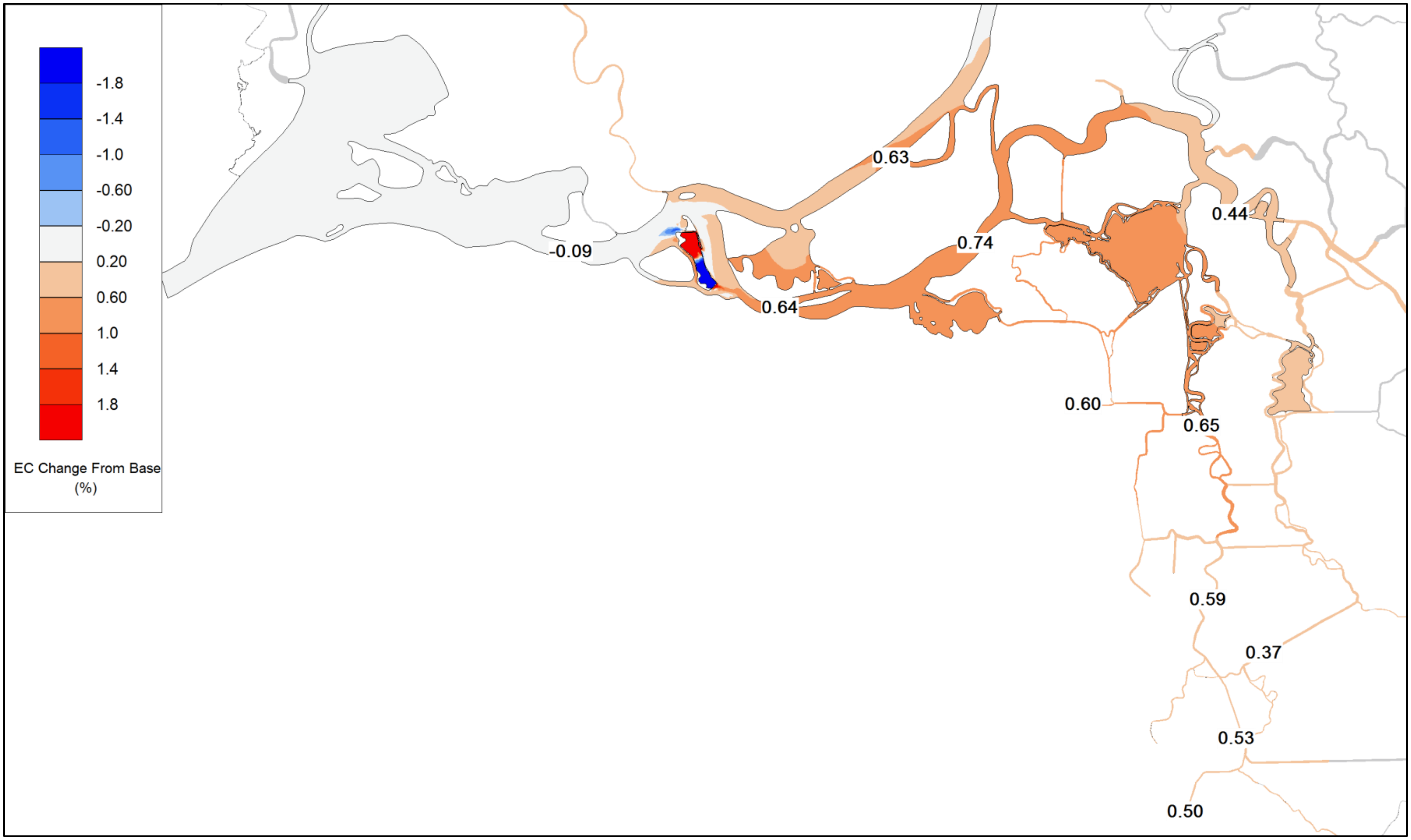

Figure 31 Alt 2: tidally averaged percent change from Base-1 EC on July 30, 2013.

Base-2

Results in Table 8 and Table 9, and in Figure 32 through Figure 40 illustrate comparisons between 2013 Base-2 and alternative EC simulation results.

Table 8 Summary of 2013 monthly average Base-2 EC and change from Base-2 EC at key locations for Alt 1 and Alt 2.

	Mallard Is			Emmaton			Antioch			Jersey Pt		
	Base EC µS/cm	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2013	6280	5.43	3.53	324	2.03	2.05	929	17.73	16.47	305	2.18	2.02
Jun 2013	7888	4.25	3.88	512	4.68	5.00	1595	29.99	28.99	432	6.08	5.78
Jul 2013	10488	-2.35	-1.67	607	4.24	4.91	2881	39.45	39.88	941	15.24	15.00
Aug 2013	10681	-2.57	-2.02	594	3.54	4.14	3213	38.45	39.28	1269	17.57	17.51
Sep 2013	9608	2.86	3.25	581	3.20	3.62	2542	35.22	35.58	1040	13.19	13.09
Oct 2013	12162	-1.79	-3.68	1295	9.42	10.92	3441	47.79	48.57	948	14.49	14.53
Nov 2013	13572	-5.35	-7.36	1360	10.15	12.34	4148	54.15	56.47	1168	18.39	18.89

	Rock Slough			ROLD034			Victoria Canal			SWP		
	Base EC µS/cm	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm		Base EC	EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2013	362	0.26	0.22	351	0.22	0.18	361	0.16	0.12	330	0.12	0.09
Jun 2013	328	1.05	0.99	319	0.82	0.77	309	0.33	0.31	343	0.58	0.54
Jul 2013	403	4.13	4.04	367	3.74	3.67	260	1.21	1.17	333	2.88	2.82
Aug 2013	634	7.48	7.49	555	6.42	6.43	330	2.58	2.57	488	5.29	5.29
Sep 2013	700	7.41	7.41	590	5.97	5.97	379	2.68	2.68	533	5.05	5.05
Oct 2013	513	4.75	4.75	452	3.79	3.81	359	1.60	1.63	433	2.97	2.99
Nov 2013	561	5.94	6.08	519	5.01	5.15	417	2.36	2.45	506	3.61	3.71

Table 9 Summary of 2013 monthly average Base-2 EC and percent change from Base-2 EC at key locations for Alt 1 and Alt 2.

	Mallard Is			Emmaton			Antioch			Jersey Pt		
	Base EC µS/cm	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2013	6280	0.09%	0.06%	324	0.62%	0.63%	929	1.88%	1.75%	305	0.71%	0.66%
Jun 2013	7888	0.05%	0.05%	512	0.91%	0.97%	1595	1.86%	1.79%	432	1.39%	1.32%
Jul 2013	10488	-0.02%	-0.02%	607	0.69%	0.80%	2881	1.36%	1.37%	941	1.60%	1.57%
Aug 2013	10681	-0.02%	-0.02%	594	0.59%	0.69%	3213	1.19%	1.21%	1269	1.37%	1.37%
Sep 2013	9608	0.03%	0.03%	581	0.55%	0.62%	2542	1.37%	1.39%	1040	1.26%	1.25%
Oct 2013	12162	-0.01%	-0.03%	1295	0.72%	0.84%	3441	1.38%	1.40%	948	1.51%	1.51%
Nov 2013	13572	-0.04%	-0.05%	1360	0.74%	0.90%	4148	1.29%	1.35%	1168	1.55%	1.60%

	Rock Slough			ROLD034			Victoria Canal			SWP		
	Base EC µS/cm	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm		Base EC	% EC change µS/cm	
		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2		Alt 1	Alt 2
May 2013	362	0.07%	0.06%	351	0.06%	0.05%	361	0.04%	0.03%	330	0.04%	0.03%
Jun 2013	328	0.32%	0.30%	319	0.26%	0.24%	309	0.11%	0.10%	343	0.17%	0.16%
Jul 2013	403	1.02%	0.99%	367	1.01%	0.99%	260	0.46%	0.45%	333	0.86%	0.84%
Aug 2013	634	1.17%	1.17%	555	1.15%	1.15%	330	0.78%	0.77%	488	1.07%	1.07%
Sep 2013	700	1.05%	1.05%	590	1.00%	1.00%	379	0.70%	0.70%	533	0.94%	0.94%
Oct 2013	513	0.92%	0.92%	452	0.83%	0.84%	359	0.45%	0.45%	433	0.68%	0.69%
Nov 2013	561	1.05%	1.08%	519	0.96%	0.98%	417	0.56%	0.58%	506	0.71%	0.73%

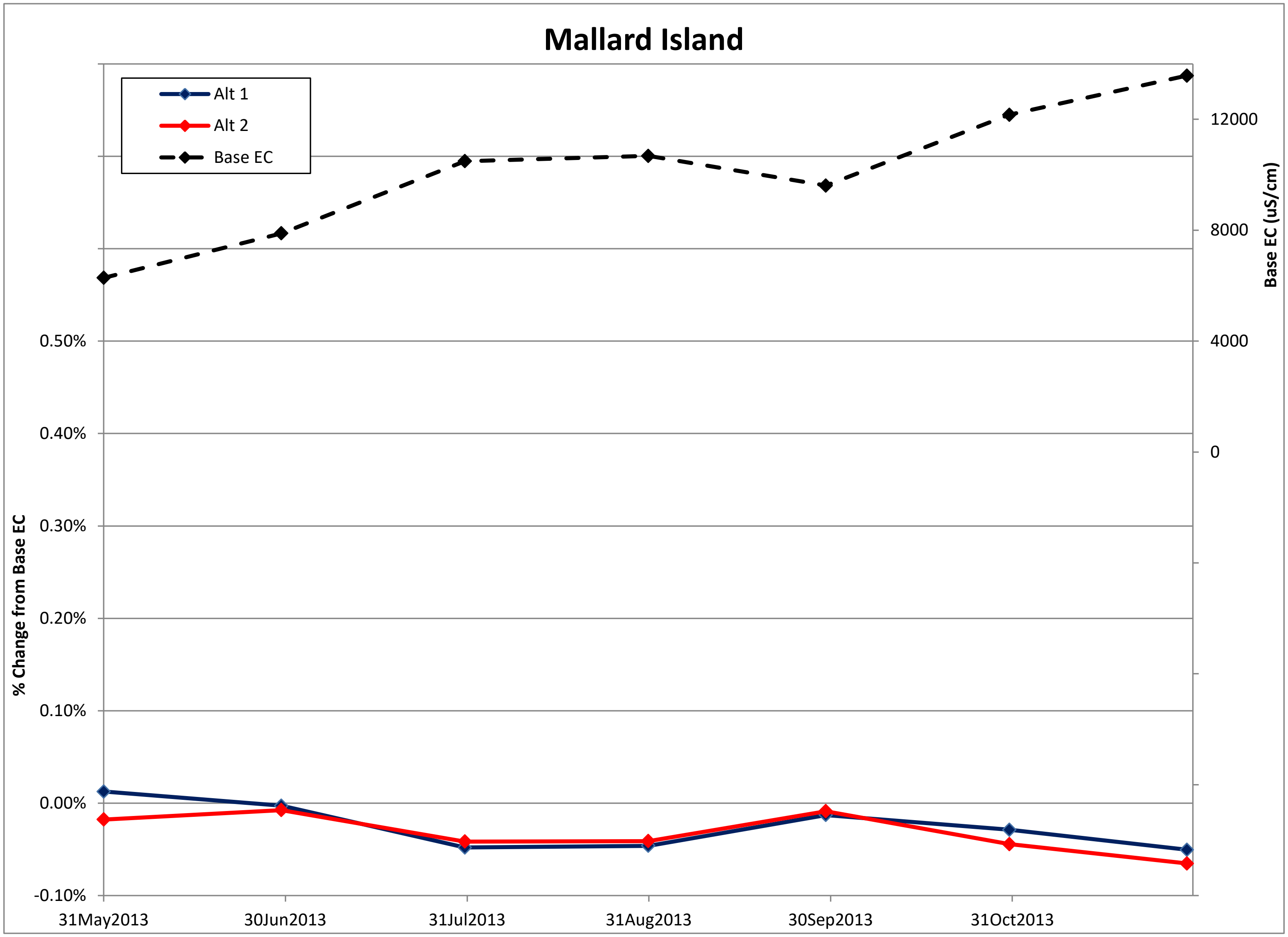

Figure 32 Time series of Alt 1 and Alt 2 monthly averaged % change from Base-2 EC plotted with Base-2 EC at Mallard Island for the 2013 analysis period.

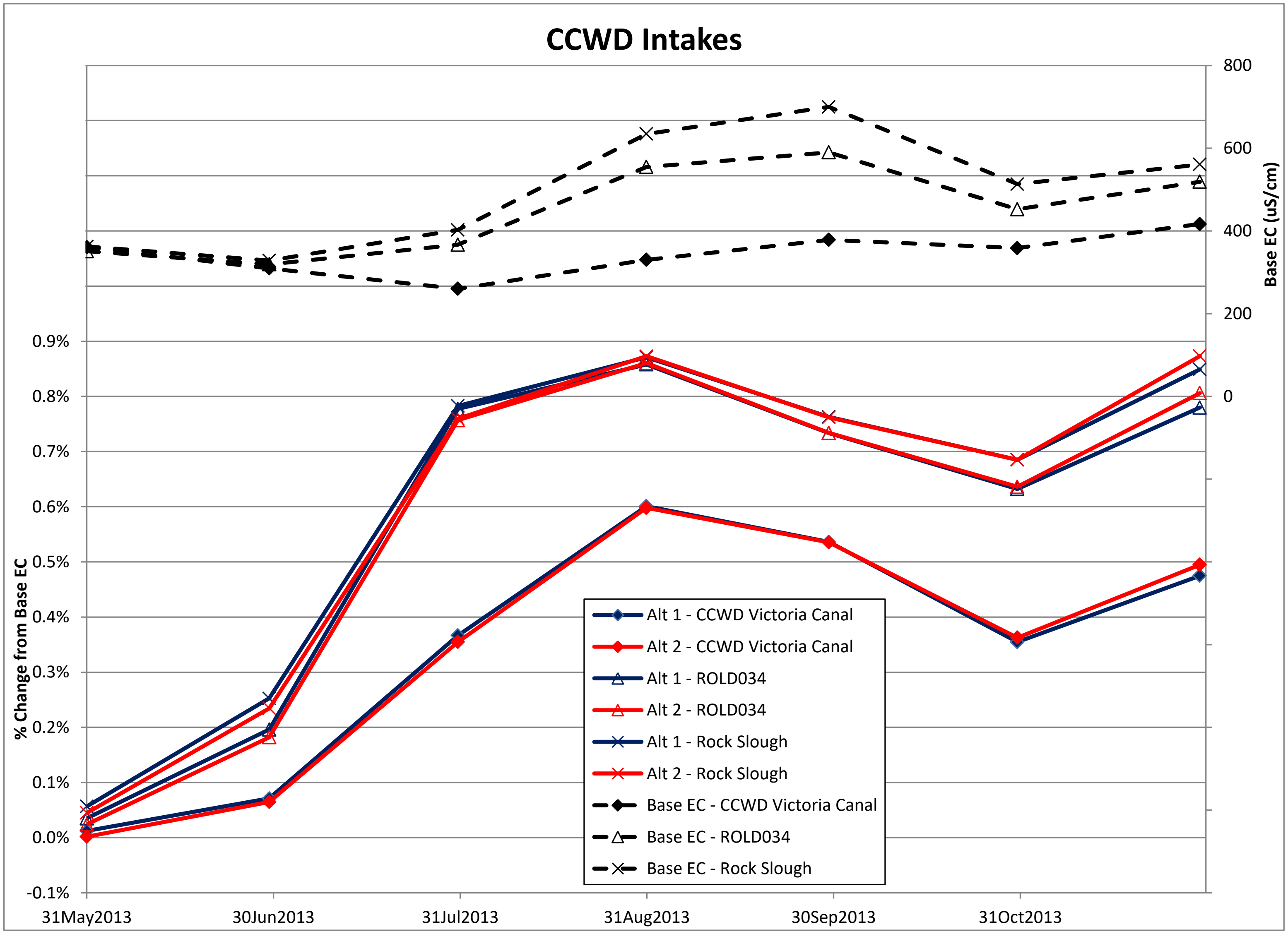

Figure 33 Time series of Alt 1 and Alt 2 monthly averaged % change from Base-2 EC plotted with Base-2 EC at the Contra Costa Water District intakes for the 2013 analysis period.

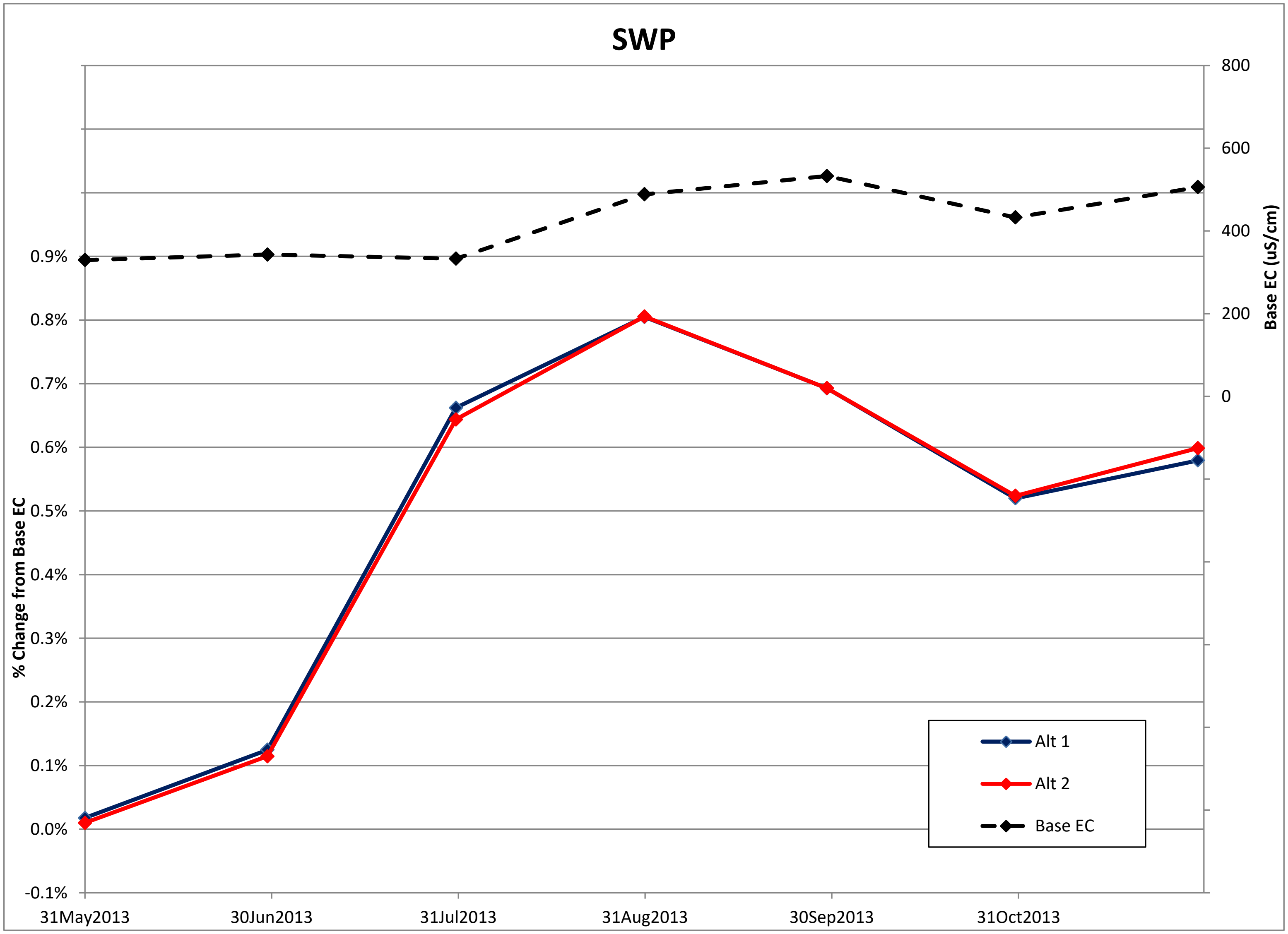

Figure 34 Time series of Alt 1 and Alt 2 monthly averaged % change from Base-2 EC plotted with Base-2 EC at SWP for the 2013 analysis period.

Alt 1 color contour plots – 2013 Base-2

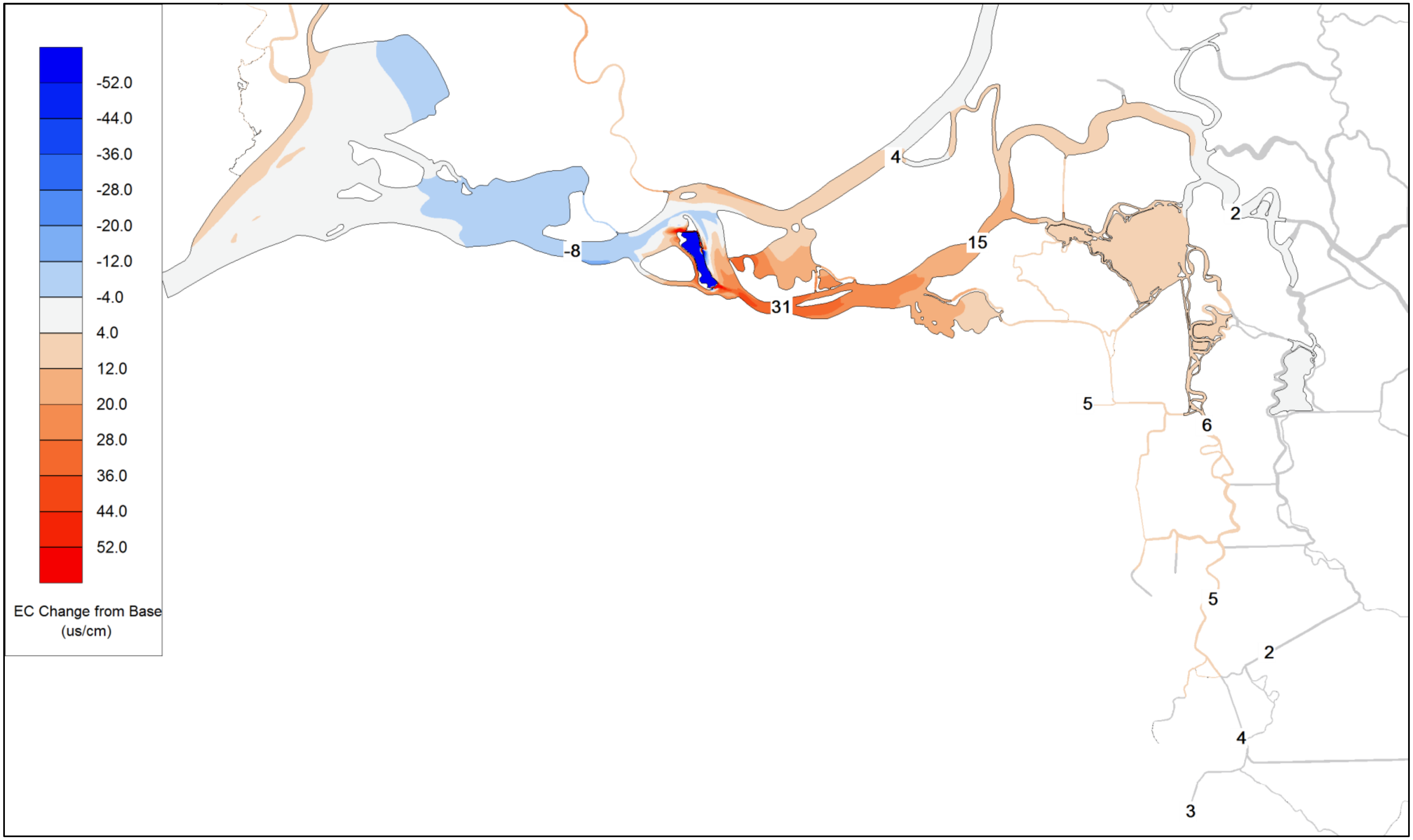

Figure 35 Alt 1: tidally averaged change from Base-2 EC on July 30, 2013.

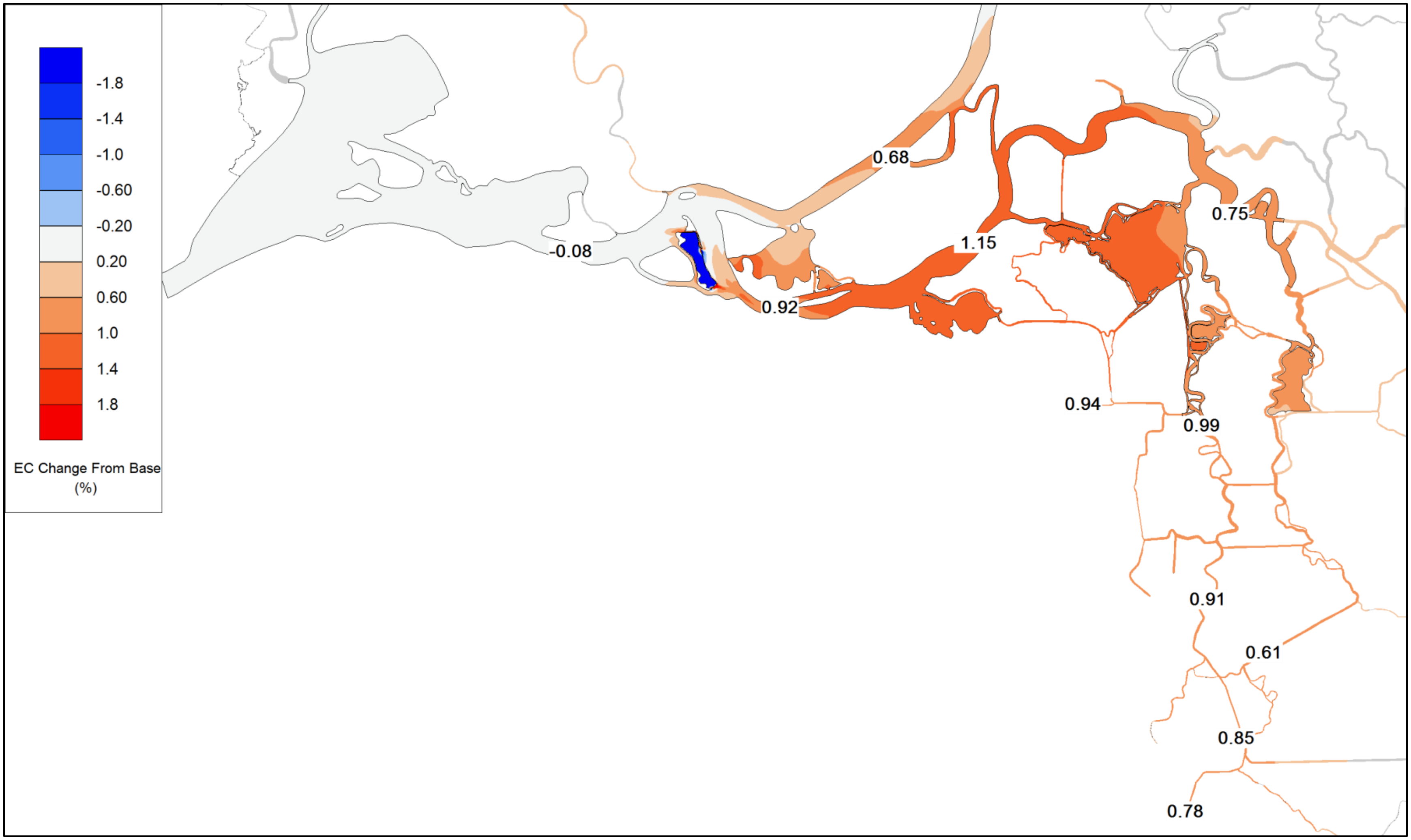

Figure 36 Alt 1: tidally averaged percent change from Base-2 EC on July 30, 2013.

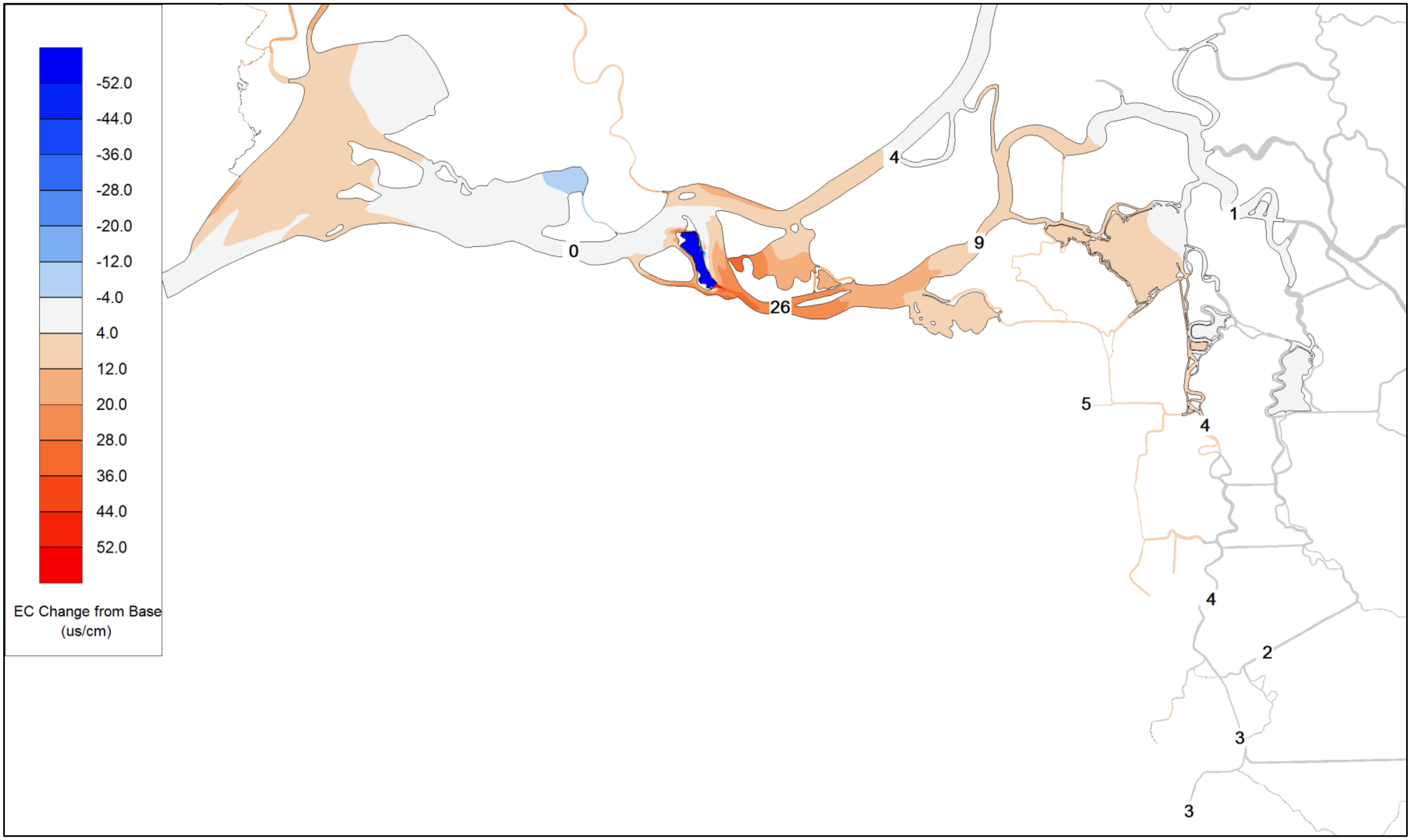

Figure 37 Alt 1: tidally averaged change from Base-2 EC on September 23, 2013.

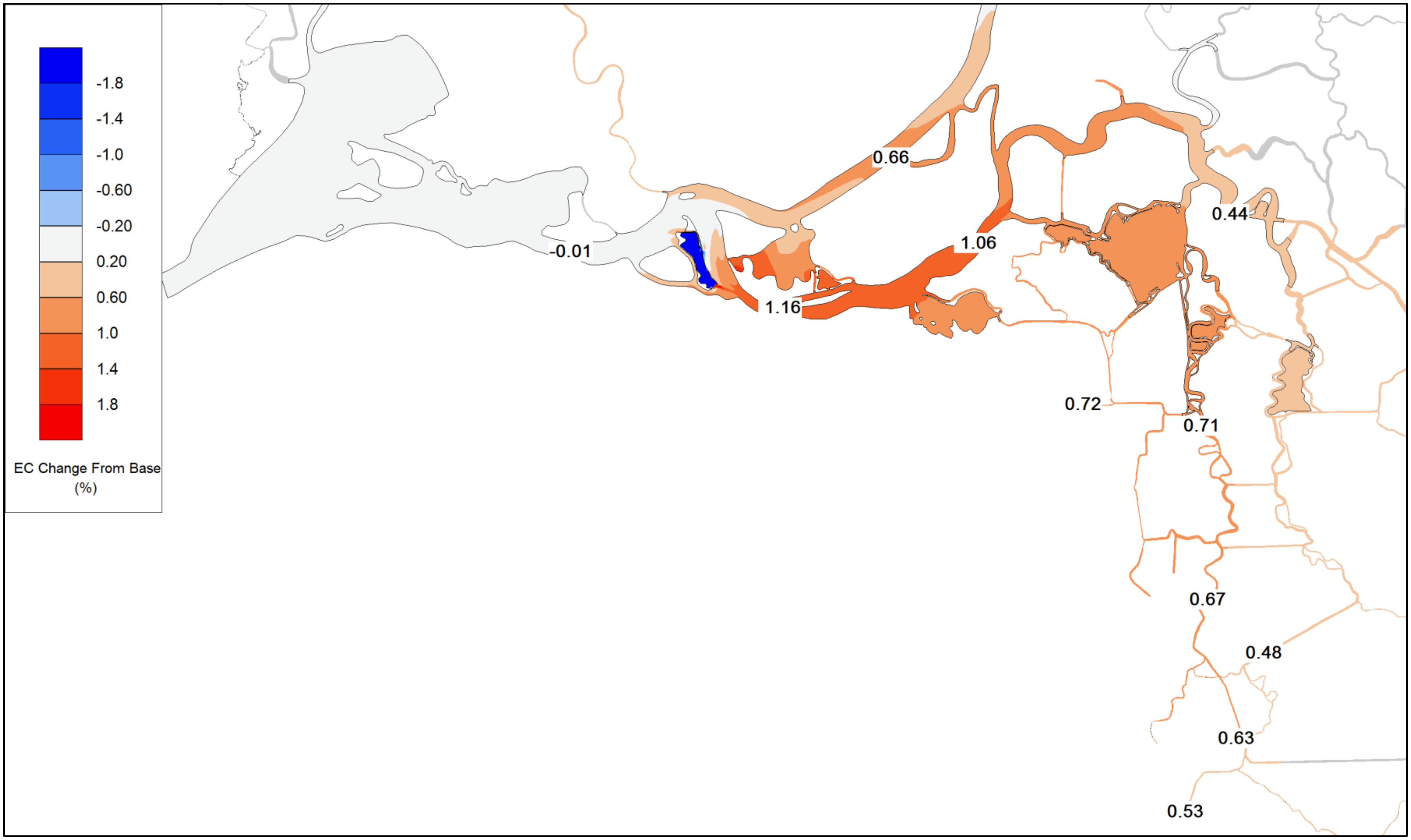

Figure 38 Alt 1: tidally averaged percent change from Base-2 EC on September 23, 2013.

Alt 2 color contour plots – 2013 Base-2

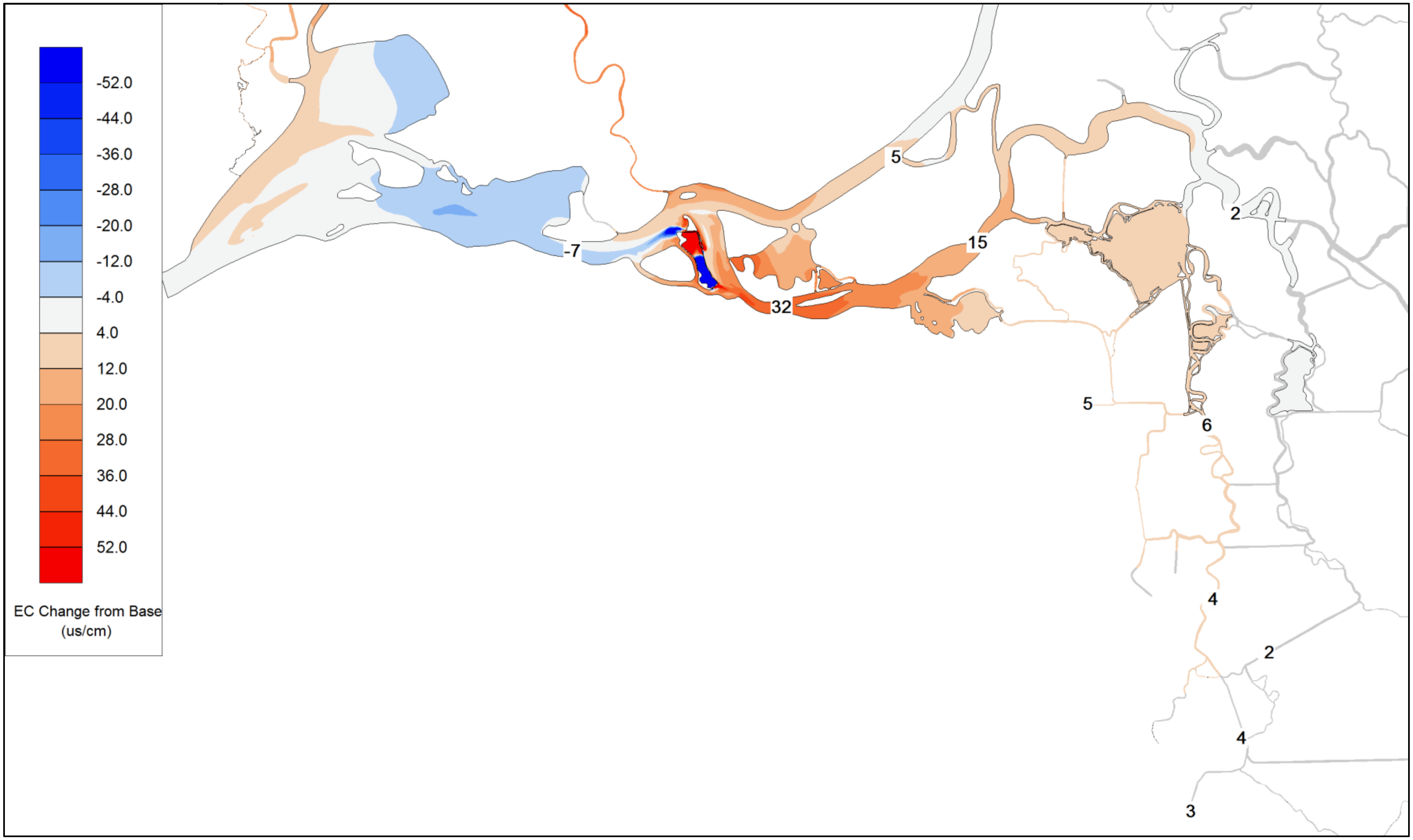

Figure 39 Alt 2: tidally averaged change from Base-2 EC on July 30, 2013.

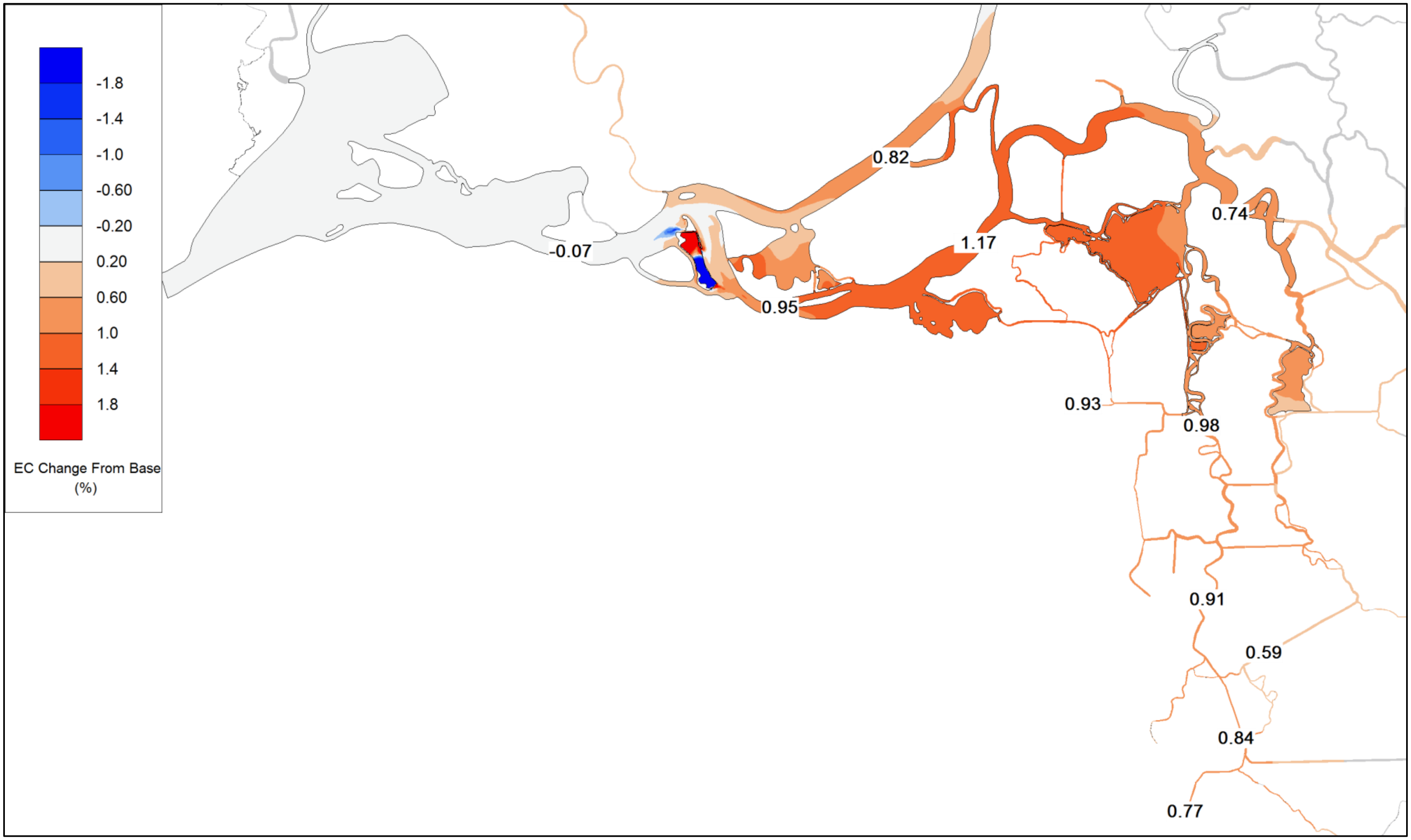

Figure 40 Alt 2: tidally averaged percent change from Base-2 EC on July 30, 2013.

Summary

Hydrodynamic and water quality simulations have been performed to assess EC impacts of proposed tidal marsh restoration alternatives on Winter Island. The analysis was performed for May through November of 2009 and 2013.

The Alt 1 restoration alternative includes widening the existing breach on the east side of the island and adding a new breach at the south end of the island. Alt 2 adds another breach at the north end of the island.

Two sets of Base and Alternative simulations were performed using different marsh plain elevations to test sensitivity to possible LiDAR data bias.

Alt 1 and Alt 2 result in similar EC impacts. Alt 1 tends to have slightly larger impacts with the Base-1 scenario, while the reverse is true with the Base-2 scenario.

The lower marsh plain elevations in the Base-2 scenario result in a noticeably large EC impact.

The largest EC impacts occur in the San Joaquin River near Antioch and Jersey Point and into False River. Changes do not exceed 1% for the Base-1 results or 2% for the Base-2 results.

References

cbec (2011). *Prospect Island Tidal Restoration Project, Summary of Bathymetric and Topographic Data Sources, Technical Memorandum*. DWR Task Order SS-02, Task 3.

DWR (1995). *Estimation of Delta Island Diversions and Return Flows,* California Department of Water Resources, Division of Planning, February 1995.

DWR (2012). *(DRAFT) Multibeam Bathymetry Project Report, Miner Slough & Sacramento Deep Water Ship Channel near Prospect Island*.

Environmental Data Solutions (EDS) (2013). *Prospect Island Tidal Wetland Restoration Project Tidal Monitoring Surveys and Conductivity Data Collection*. DWR Task Order SS-02, Task 3. Contract No. 420009291. January 2013.

RMA (2003). RMASIM Users Guide, April 2003.

USACE (2005). Sacramento River Deep Water Ship Channel, California, Maintenance Dredging Site – Task Order #6.

USACE (2002). Sacramento and San Joaquin River Basins Comprehensive Study. US Army Corps of Engineers Sacramento District, December 2002.

WWR (2006). Integrated Regional Wetland Monitoring Pilot Project, Physical Processes Team Field Data Collection Report, December 2003 to September 2006. December 2006.

Appendix

Model Boundary Conditions

The RMA Delta hydrodynamic model operation requires specification of the tidal stage at Martinez and inflow and withdrawal rates at other external boundaries as shown in Figure 3. Water quality model operation requires specification of quality boundary conditions at the stage and inflow boundaries.

The tidal boundary was set at Martinez using observed 15-minute stage and EC data. The average of surface and bottom EC was used. The RMA model was run in a density-coupled mode, with simulated EC used to establish the density setup of the Delta stage.

Inflows include:
Sacramento River above American River
American River near Sacramento
San Joaquin River near Vernalis
Yolo Bypass and Yolo Bypass Toe Drain
Mokelumne River near Thornton
Cosumnes River
Calaveras River near Stockton
Lindsey Slough, Upper Cache and Hass Slough inflows

Exports/Diversions include:
State Water Project (SWP), Clifton Court Forebay gates.
Central Valley Project (CVP) Tracy Pumping Plant
Contra Costa Water District (CCWD) intakes at Rock Slough, Old River and Victoria Canal
North Bay Aqueduct (NBA), Barker Slough Pumping Plant
Delta Island Consumptive Use (DICU), throughout Delta
Lindsey Slough, Upper Cache and Hass Slough diversions

The following boundary condition data sources were used:

- CDEC: http://cdec.water.ca.gov
- DWR-DAYFLOW: http://www.water.ca.gov/dayflow/
- DWR-DES (Division of Environmental Services): http://www.water.ca.gov/environmentalservices/
- DWR-DMS (Delta Modeling Section): http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/

- DWR-NCRO (North Central Region Office): http://www.cd.water.ca.gov/
- DWR-WDL (Water Data Library): http://www.water.ca.gov/waterdatalibrary/
- SCWA (Solano County Water Agency): http://www.scwa2.com/
- USGS-NWIS (National Water Information System): http://waterdata.usgs.gov/nwis

DICU flows are applied on a monthly average basis for all simulation periods. These flows incorporate channel depletions, infiltration, evaporation, and precipitation, as well as Delta island agricultural use. DICU flow and EC values and were derived from monthly DSM2 input values (DWR, 1995).

Gate and barrier operations are also included in the model. Permanent gates and temporary barriers represented in the model include the Delta Cross Channel, Old River near Tracy (DMC) barrier, Old River at Head barrier, Middle River barrier, Montezuma Slough salinity control gates and Grant Line Canal barrier. The historical operation schedules for these structures are available over the Web.

Delta Cross Channel gates:
http://www.usbr.gov/mp/cvo/vungvari/Ccgates.pdf

Suisun Marsh Salinity Control Gates:
http://www.water.ca.gov/suisun/dataReports/docs/histsmscgop.pdf

South Delta Temporary Barriers
- Old River near Tracy (DMC) temporary barrier
- Old River at Head temporary barrier
- Middle River temporary barrier
- Grant Line Canal temporary barrier

http://baydeltaoffice.water.ca.gov/sdb/tbp/web_pg/tempbar/weekly.cfm

2009 Boundary Conditions

Hydrodynamic and water quality models were run for the January – November 2009 period. January – April were used for model spin-up and May through November was used for EC impact analysis. This period includes below normal, dry and critically dry conditions (see http://cdec.water.ca.gov/cgi-progs/iodir/wsihist).

Tide

The tidal boundary stage shown in Figure 41 was set using 15-minute stage data from CDEC. Figure 42 shows the stage for a brief period in 2009.

Inflows

Time series of daily average inflow boundary conditions are plotted in Figure 43 to Figure 45 for the 2009 simulation period. These flows are applied for the Sacramento River, American River, Yolo Bypass/Cache Slough area inflows, San Joaquin River, Cosumnes River, Mokelumne River, and Calaveras River.

Exports

Delta exports applied in the model include Clifton Court (SWP), CVP, Contra Costa exports at Rock Slough and Old River intakes, and North Bay Aqueduct intake at Barker Slough. Exports are plotted for the 2009 period in Figure 46 and Figure 47. Although 10-minute export flows are applied at the SWP, daily averages are plotted for ease of viewing.

EC

Time series of EC are applied at Martinez and major River inflows as shown in Figure 48 and Figure 49. Cache Slough inflow EC is set constant at 500 µmhos/cm and Lindsey Slough inflow is set constant at 200 µmhos/cm.

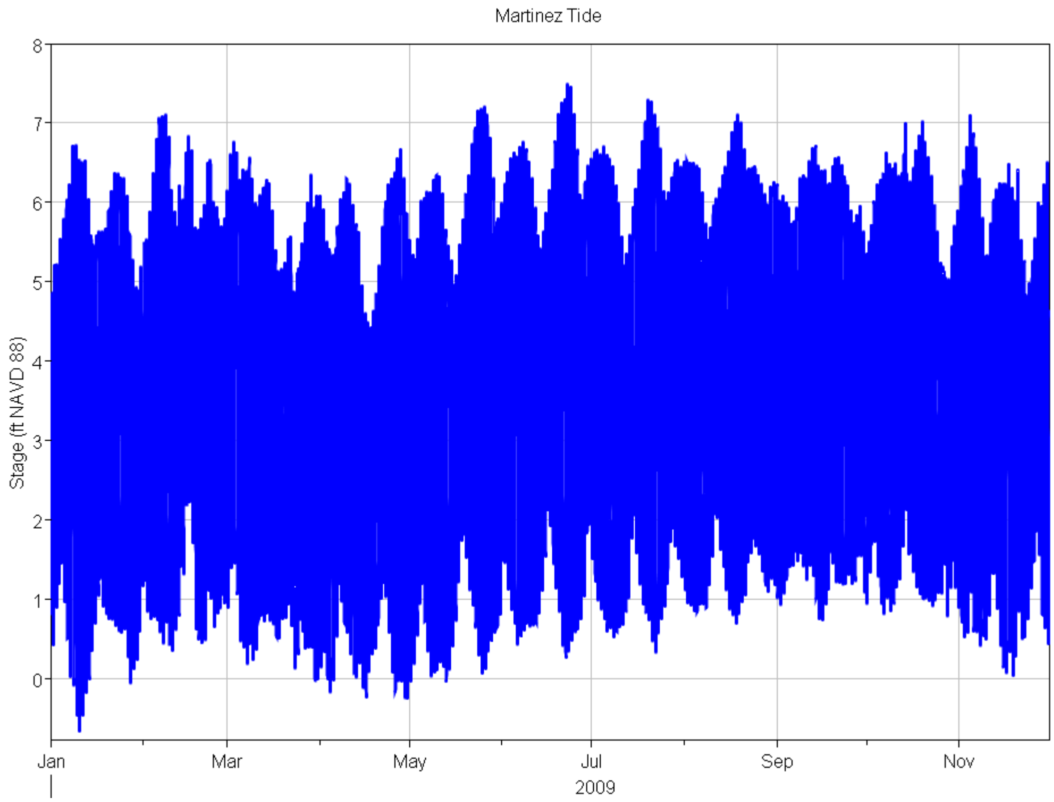

Figure 41 Martinez stage applied at tidal boundary for the 2009 simulation period.

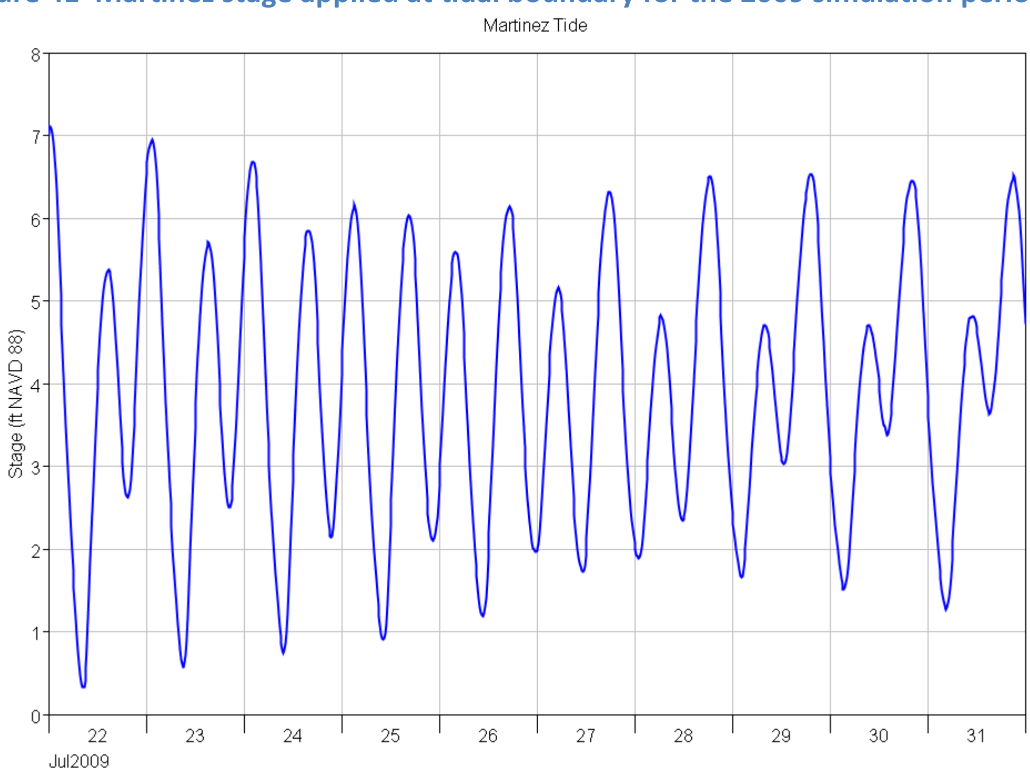

Figure 42 Tidal boundary (expanded scale), July 2009.

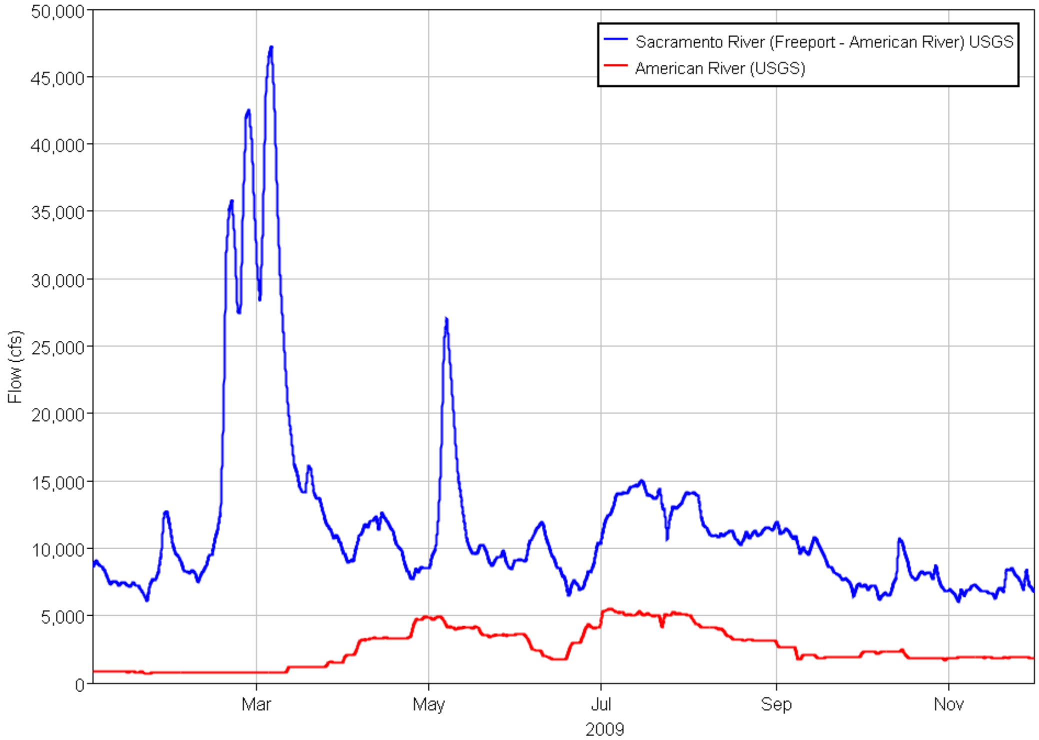

Figure 43 Sacramento River and American River inflow boundary conditions for the 2009 simulation period.

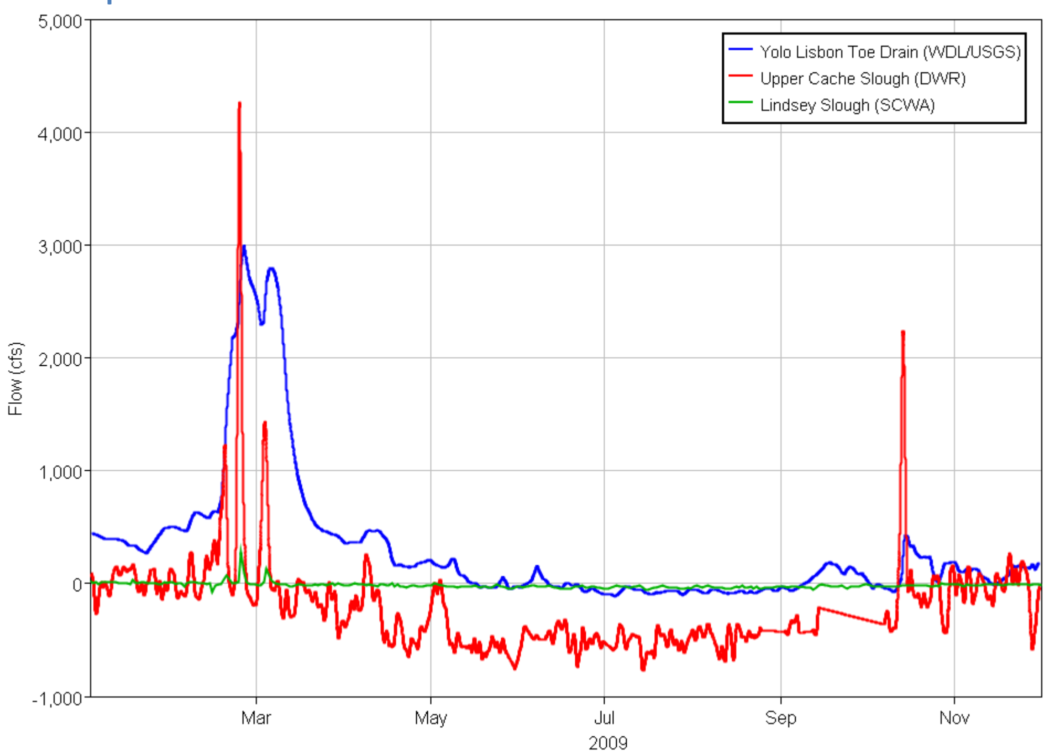

Figure 44 Yolo Bypass/Cache Slough area inflow boundary conditions for the 2009 simulation period.

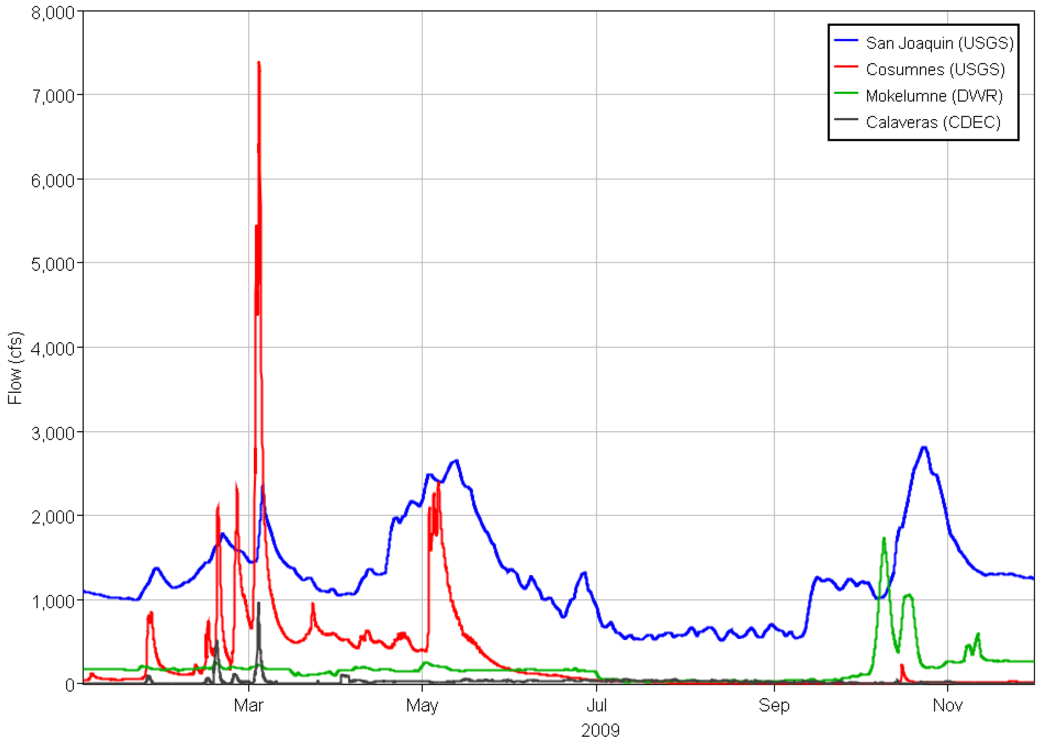

Figure 45 San Joaquin River, Cosumnes River, Mokelumne River and Calaveras River inflow boundary conditions for the 2009 simulation period.

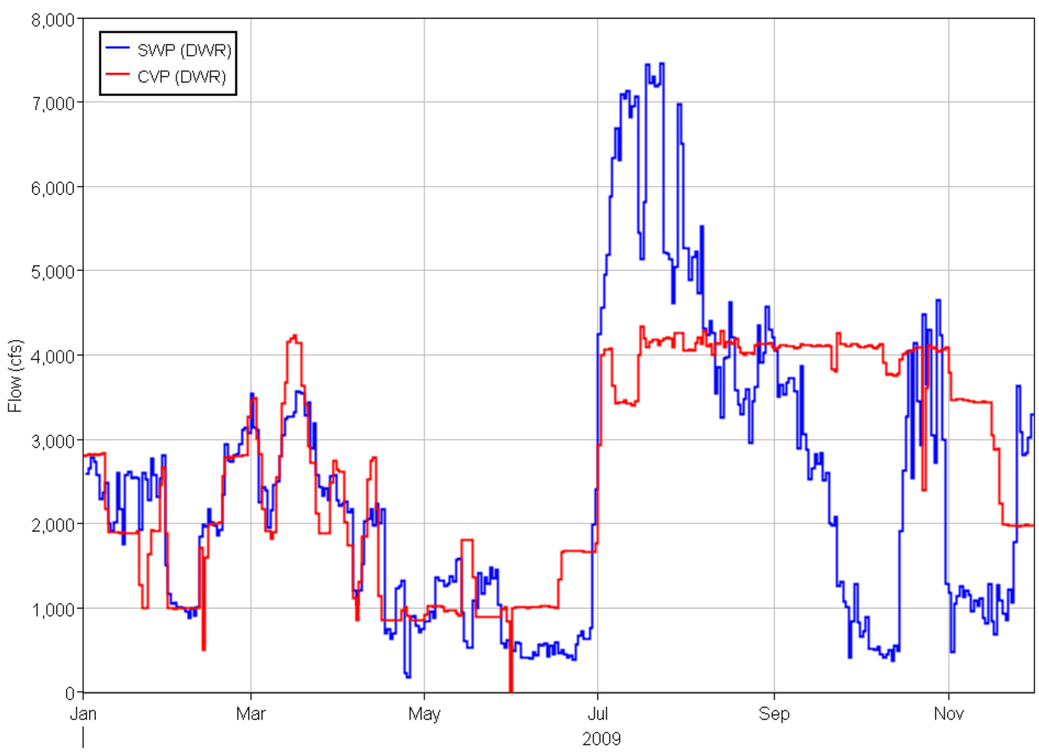

Figure 46 Clifton Court and CVP export boundary conditions for the 2009 simulation period.

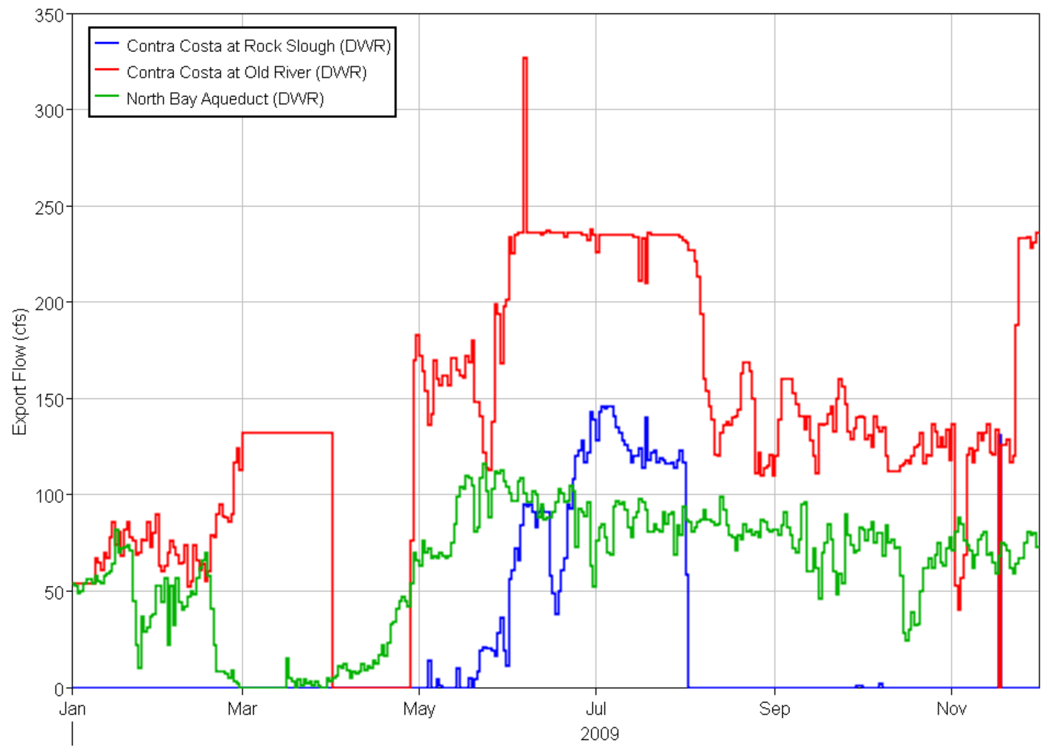

Figure 47 Contra Costa and North Bay Aqueduct export boundary conditions for the 2009 simulation period.

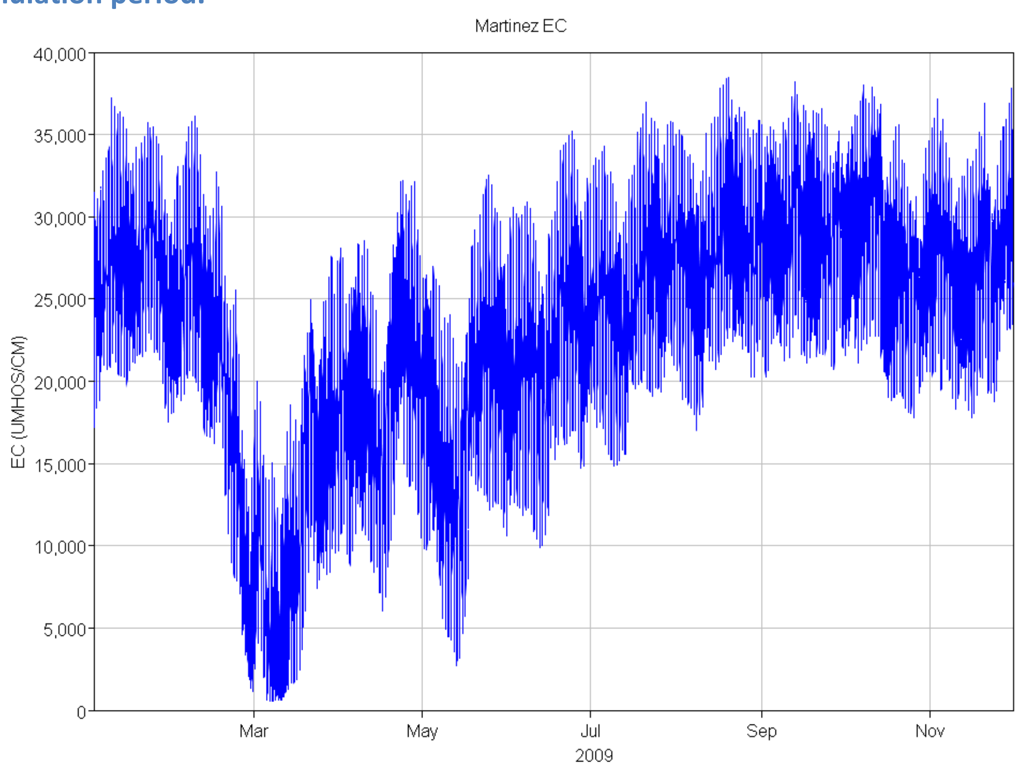

Figure 48 Martinez EC boundary condition for 2009 simulation period.

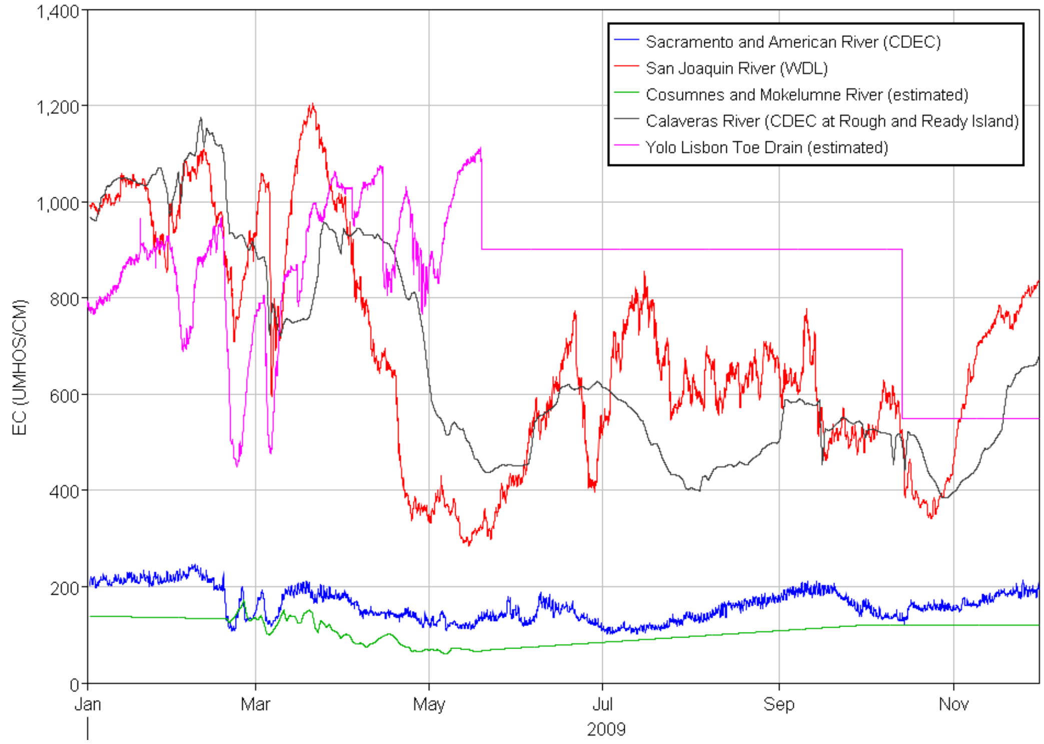

Figure 49 Time-varying EC boundary conditions for the 2009 simulation period.

2013 Boundary Conditions

Hydrodynamic and water quality models were run for the January – November 2013 period. January – April were used for model spin-up and May through November was used for EC impact analysis. This period includes dry and critically dry conditions (see http://cdec.water.ca.gov/cgi-progs/iodir/wsihist).

Tide

The tidal boundary stage shown in Figure 50 was set using 15-minute stage data from CDEC. Figure 51 shows the stage for a brief period in 2009.

Inflows

Time series of daily average inflow boundary conditions are plotted in Figure 52 to Figure 54 for the 2013 simulation period. These flows are applied for the Sacramento River, American River, Yolo Bypass/Cache Slough area inflows, San Joaquin River, Cosumnes River, Mokelumne River, and Calaveras River.

Exports

Delta exports applied in the model include Clifton Court (SWP), CVP, Contra Costa exports at Rock Slough and Old River intakes, and North Bay Aqueduct intake at Barker Slough. Exports are plotted for the 2013 period in Figure 55 and Figure 56. Although 10-minute export flows are applied at the SWP, daily averages are plotted for ease of viewing.

EC

Time series of EC are applied at Martinez and major River inflows as shown in Figure 57 and Figure 58. Cache Slough inflow EC is set constant at 800 µmhos/cm and Lindsey Slough inflow is set constant at 200 µmhos/cm.

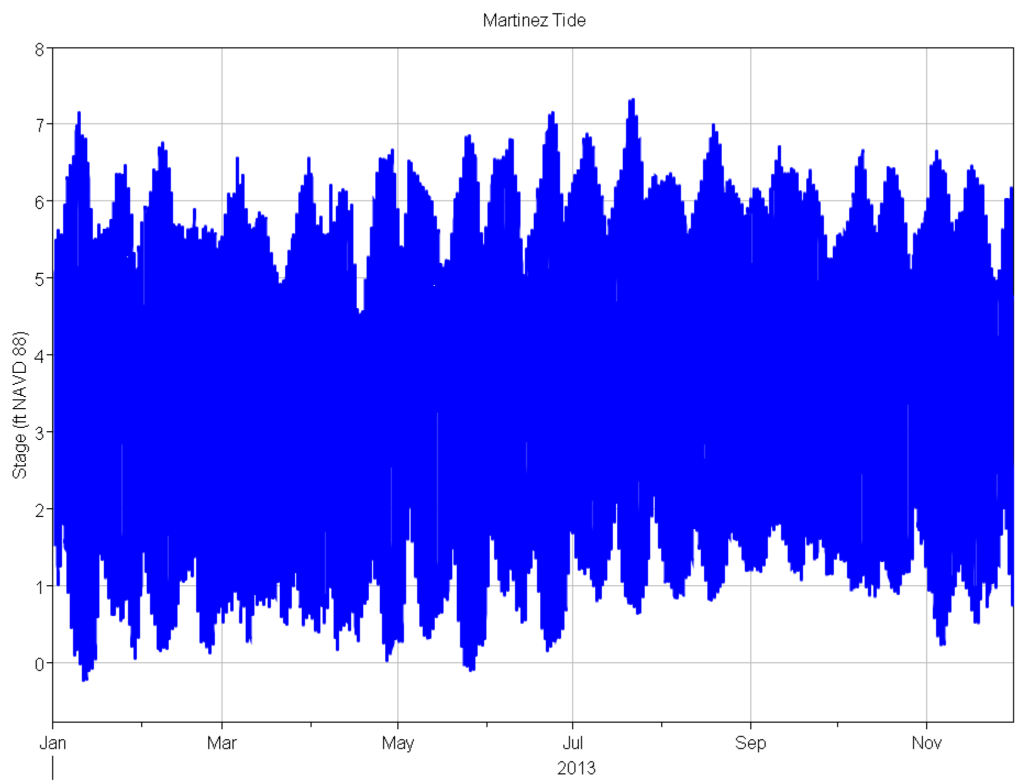

Figure 50 Martinez stage applied at tidal boundary for the 2013 simulation period.

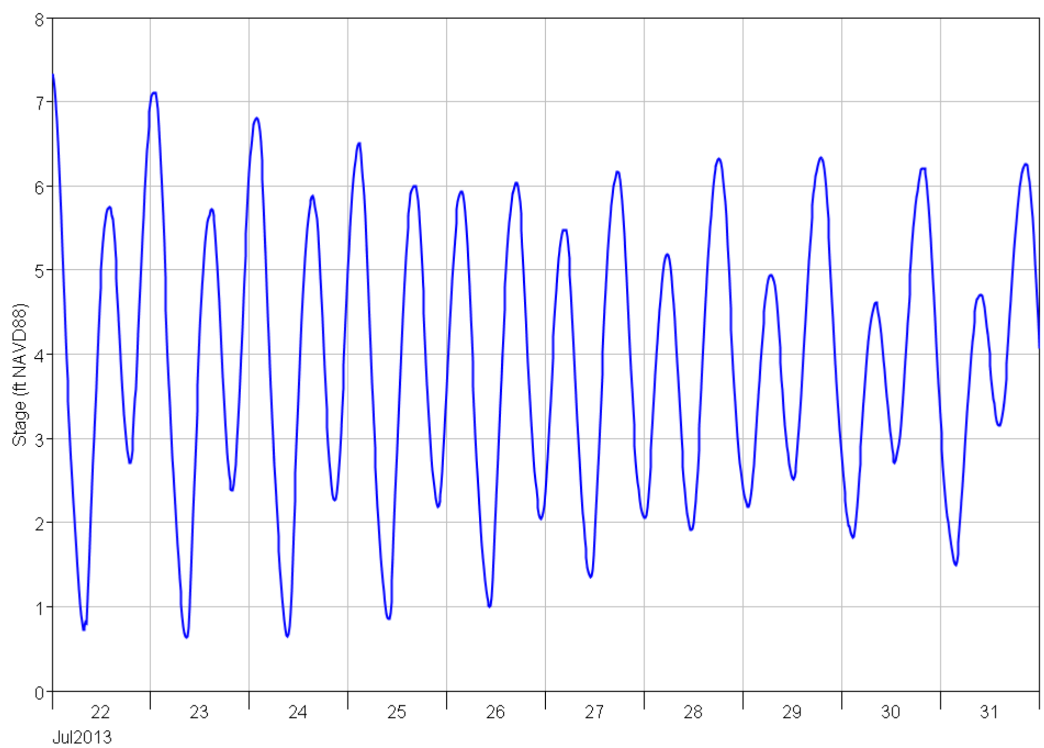

Figure 51 Tidal boundary (expanded scale), July 2013.

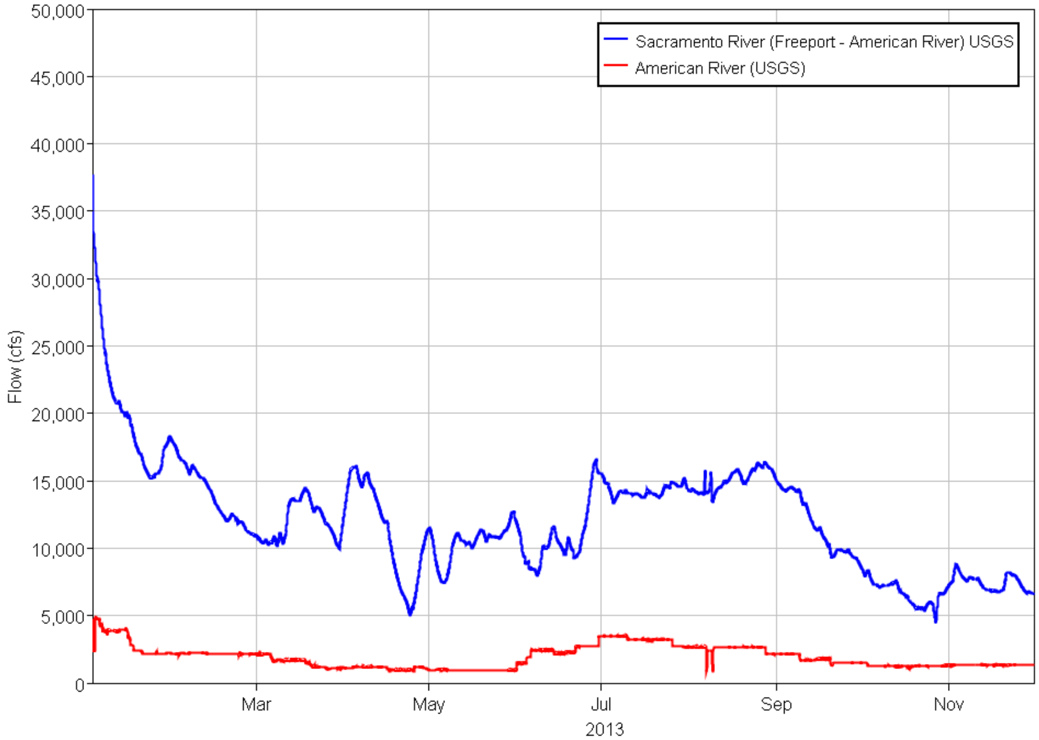

Figure 52 Sacramento River and American River inflow boundary conditions for the 2013 simulation period.

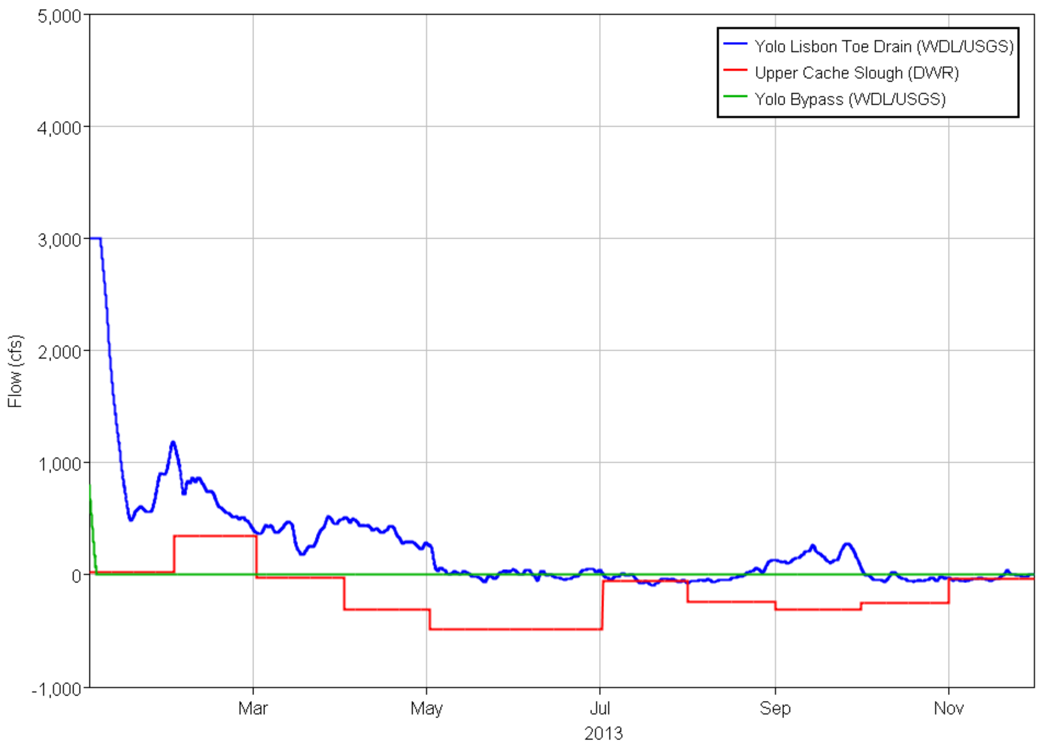

Figure 53 Yolo Bypass/Cache Slough area inflow boundary conditions for the 2013 simulation period.

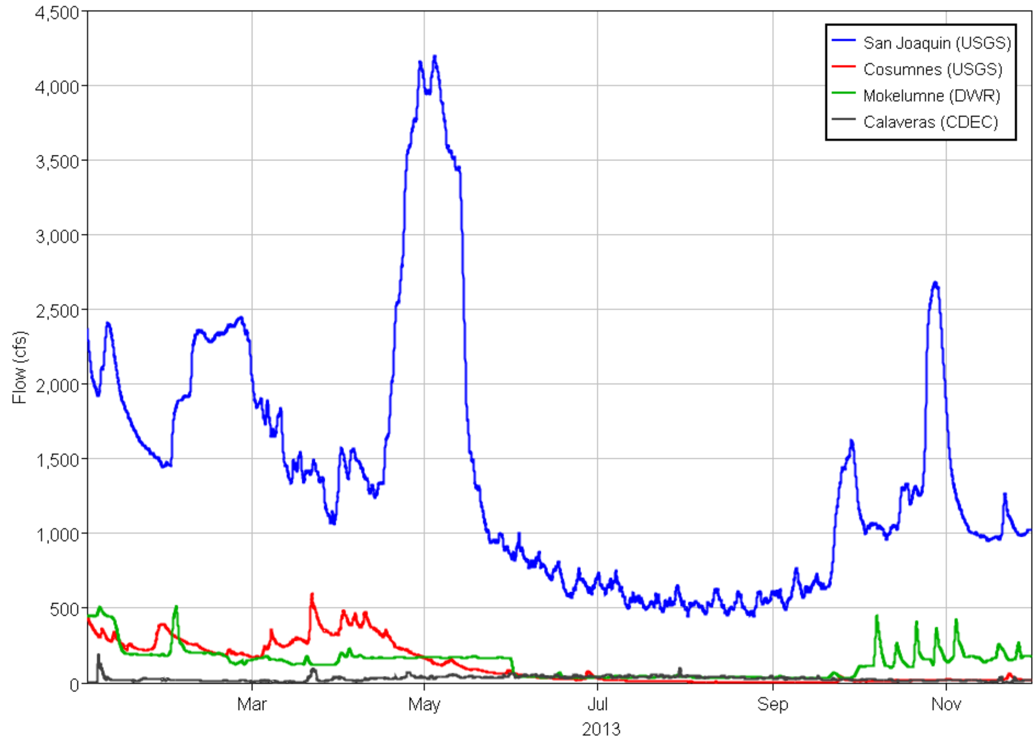

Figure 54 San Joaquin River, Cosumnes River, Mokelumne River and Calaveras River inflow boundary conditions for the 2013 simulation period.

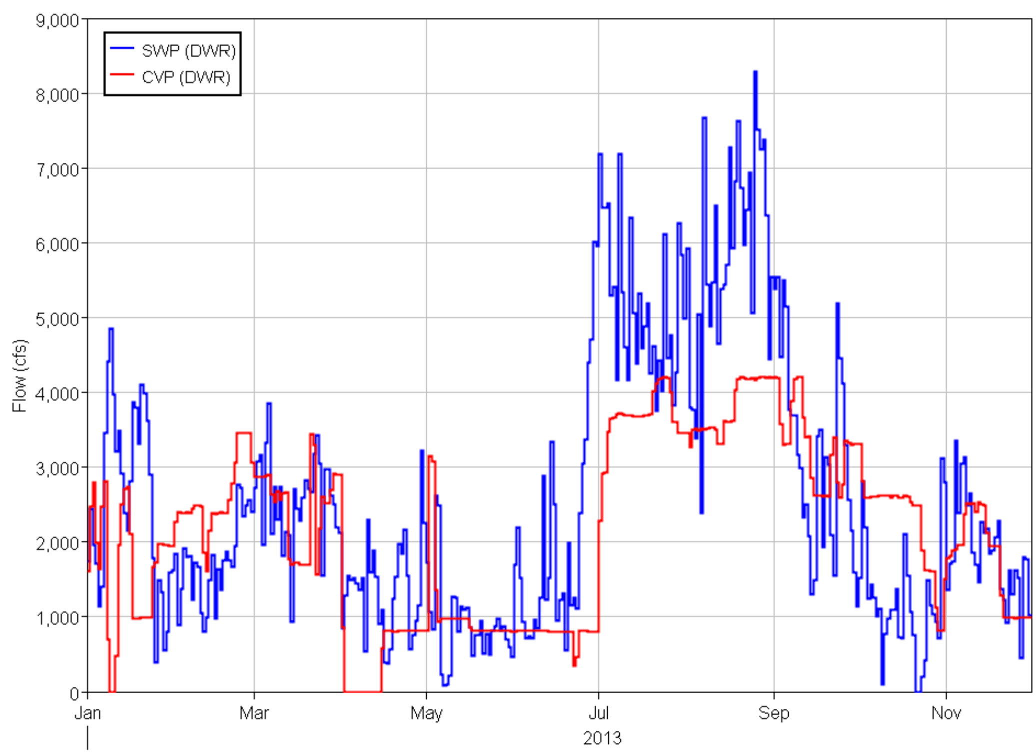

Figure 55 Clifton Court and CVP export boundary conditions for the 2013 simulation period.

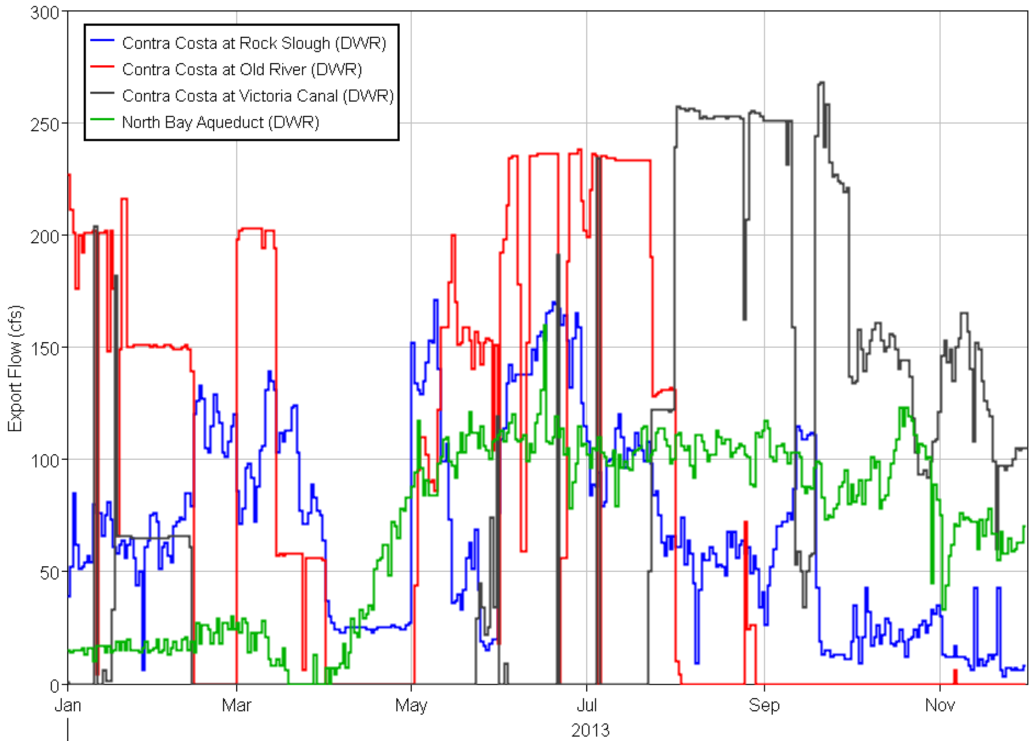

Figure 56 Contra Costa and North Bay Aqueduct export boundary conditions for the 2013 simulation period.

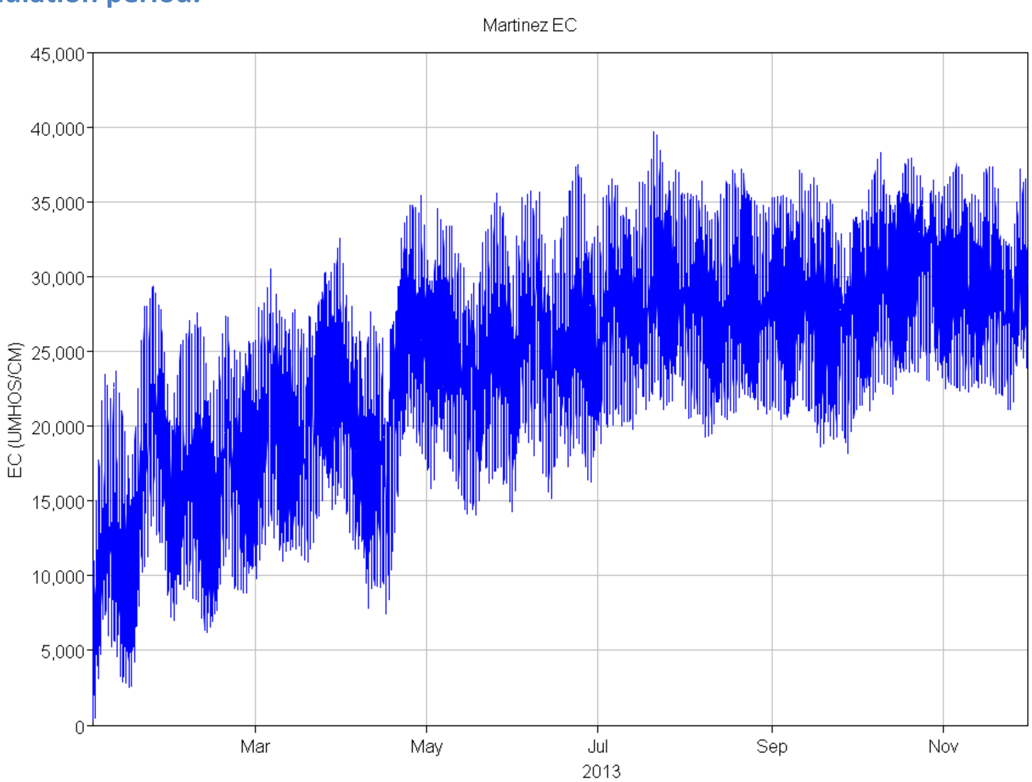

Figure 57 Martinez EC boundary condition for 2013 simulation period.

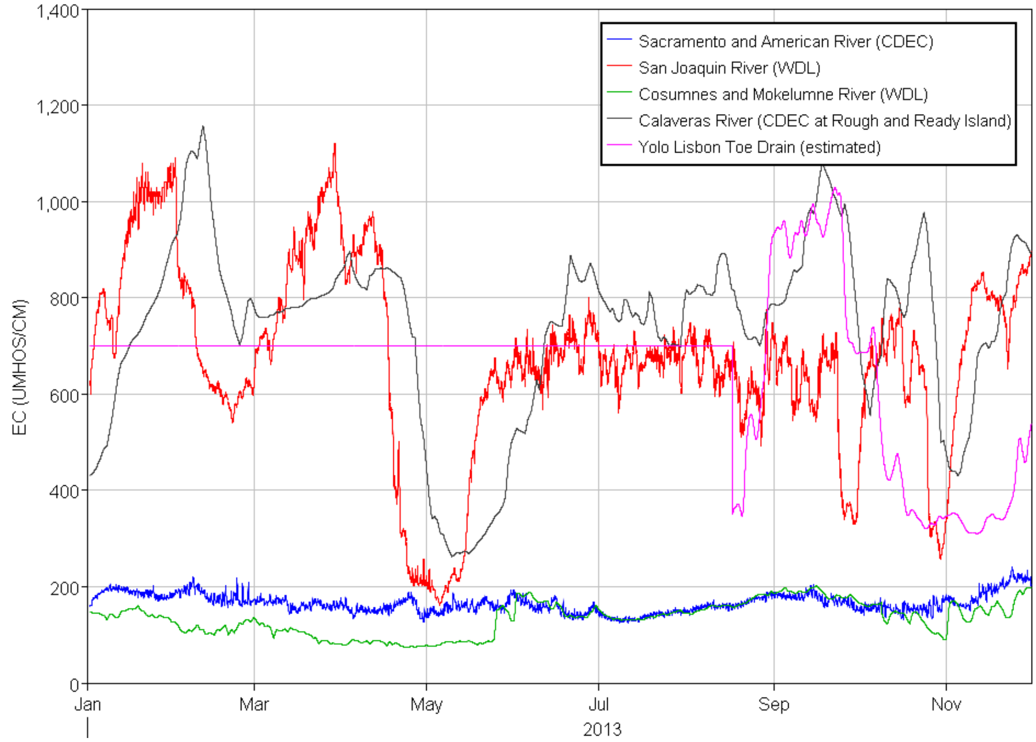

Figure 58 Time-varying EC boundary conditions for the 2013 simulation period.